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ON

URINE, URINARY DEPOSITS

AND

CALCULI:

THEIR MICROSCOPICAL AND CHEMICAL EXAMINATION, INCLUDING THE CHEMICAL AND MICROSCOPICAL APPARATUS REQUIRED, AND TABLES FOR THE PRACTICAL EXAMINATION OF THE URINE IN HEALTH AND DISEASE;

THE ANATOMY AND PHYSIOLOGY OF THE KIDNEY,

WITH

UPWARDS OF SIXTY ORIGINAL ANALYSES OF THE URINE IN DISEASE, AND GENERAL REMARKS ON THE TREATMENT OF CERTAIN URINARY DISEASES.

Illustrated with numerous Original Wood Engravings.

BY

LIONEL S. BEALE, M.B., F.R.S.,

FELLOW OF THE ROYAL COLLEGE OF PHYSICIANS; PHYSICIAN TO KING'S COLLEGE HOSPITAL
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THESE PAGES

ARE DEDICATED TO THOSE WHO

WORKED WITH THE AUTHOR IN HIS LABORATORY;

AS AN ACKNOWLEDGMENT OF THE GRATITUDE

WHICH HE WILL ALWAYS FEEL TOWARDS MANY FRIENDS,

WHO, BY ATTENDING HIS FIRST LECTURES,

GAVE HIM THE

WARMEST SUPPORT AND ENCOURAGEMENT

AT AN EARLY PERIOD OF HIS CAREER

AS A TEACHER.

PREFACE.

The lectures which are now published were first given in November 1852, at a laboratory which I had arranged for the study of those branches of chemistry and microscopical inquiry which have a special bearing on medicine. Several courses of lectures and demonstrations were given during the seven succeeding years; but of late, increased work in other departments has prevented me from devoting so much of my time to this branch of teaching.

The course on urine included oral lectures and practical demonstrations, in which every pupil performed the experiments with his own hands, according to the directions given in the Tables, which will be found at page 401 of the present work.

The lectures (to page 362) were first published in the *British Medical Journal*, and are now printed in a collected form, with several additions. I have endeavoured to restrict myself, as far as possible, to those parts of the subject which are of practical importance in investigating the nature of a case. It must be borne in mind that the lectures were given to practitioners, most of whom had far larger experience in practice than myself. Little advantage, therefore, could have resulted under these circumstances from discussing special questions connected with the treatment of disease, and almost the whole time was devoted to the practical examination of the urine and urinary deposits by the microscope and by applying the

appropriate tests. I have thought it right to retain this character in the present work, and only a few very general remarks will be found with reference to the treatment of urinary diseases.

I have had frequent occasion to refer to numerous works, and have inserted many references in the text between brackets. The names of almost all the authors consulted, will also be found in the index.

Nearly all the analyses have been made by myself, and the drawings have in most cases been copied by me on the blocks, which were afterwards engraved. Those illustrating the chapter on the kidney have been very recently copied from specimens carefully prepared. Only comparatively few illustrations of the salts of the urine and of urinary deposits will be found in this work, as they have been already published in the *Illustrations*, to which numerous references have been made. I have endeavoured, as far as possible, to give accurate copies of the objects; and almost all the drawings in both works have been traced directly on the wood-blocks or lithographic stones. Each object has been represented of the exact size it appeared. The magnifying power is given, and a scale appended, by which any one can measure every object.

References to different parts of the work are inserted where required, especially in the Tables at the end of the volume. Pains have been taken to arrange the subjects to be discussed in the most convenient manner. A glance at the arrangement which immediately follows will at once give the reader an idea of the contents of the book, and the order in which the subjects are treated of.

LIONEL S. BEALE.

61, *Grosvenor Street, W., March* 1861.

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ON

URINE, URINARY DEPOSITS, AND CALCULI.

LECTURE I.

Note-Book; Conical Glasses for examining Urine; Quantity of Urine; Colour of Urine; Smell of Urine; Clearness or Turbidity; Consistence; Deposit; Specific Gravity; Methods of taking the Specific Gravity; Reaction; Acid Urine; Alkaline Urine, from the presence of Volatile or Fixed Alkali.

GENTLEMEN,—It will be my endeavour, in the present course, to combine the advantages of an oral lecture with those of a practical demonstration; and I think you will agree with me in the opinion that, in this manner, a greater amount of information may be gained in a short time, and its practical bearing upon the investigation of disease shown more satisfactorily than by listening to an ordinary lecture. I propose, therefore, to devote the first half-hour to a short description of the substances which you will afterwards have an opportunity of examining for yourselves. The remaining hour and a half will be occupied in subjecting the different constituents of the urine to microscopical and chemical investigation in the laboratory.

The first part of my course will comprehend the examination of healthy urine; and then I propose to give one demonstration upon the *microscopical examination* of those urinary deposits most frequently brought under the notice of the physician, and the changes which lead to the formation of casts of

the uriniferous tubes. The examination of various *morbid* specimens of urine, and the detection of *extraneous matters*, will then be considered. Lastly, I propose to make a few remarks upon the different forms of *urinary calculi*, and to consider the conditions of the urine which lead to their formation.

My chief aim will be to direct your attention especially to those parts of the subject which bear upon the practical examination of the urine, with reference to diagnosis and the investigation of disease; and I shall only dwell upon those chemical processes and microscopical researches which are adapted for the *clinical examination* of this secretion, and which may, with a little trouble, be pursued by the practitioner. I shall briefly allude to the nature of the morbid changes which we are able to discover by an examination of the urine, but shall not attempt to discuss in detail the treatment to which the patient should be subjected,—for two reasons: first, because many of you are as well able to offer an opinion on this part of the question as myself; and secondly, because, as we all know, in the majority of these cases, the difficulty lies in the diagnosis: the exact nature and history of the morbid changes having been ascertained, the proper plan of treatment often at once suggests itself to the practitioner.*

Before I describe the different substances entering into the composition of healthy urine, I must refer to some preliminary operations to which the specimen should be subjected before it is attempted to separate its chemical constituents from each other, or to examine any deposit that may have been formed in the microscope.

Note-Book. The result of every observation should be carefully entered in a note-book at the time it is made; and it is often of the greatest importance to make a sketch of the microscopical characters of a deposit, and to append a careful but short description of the specimen at the time the drawing

* This course of Lectures was delivered only to practitioners.

is made, as well as notes of the case from which the urine was obtained. (On drawing and measuring objects, see *The Microscope in its Application to Practical Medicine*, 2nd edit., p. 33.)

Now, suppose a specimen of urine brought to you for examination, how is the investigation to be commenced? what are the first points which should attract your notice? in what order should they be observed? and how are you to ascertain the nature of constituents which are dissolved in the fluid, or which form a visible deposit?

The perfectly fresh urine should be poured into a conical glass vessel.

Conical Glasses for examining Urine. The best form of conical glass for placing specimens of urine in, is one sug-

Fig. 1.

gested by my colleague Dr. Budd. It is represented in Figure 1. Its advantages are these—that the specific gravity may first be taken, and then the fluid allowed to stand, for the subsidence of any deposit, without transference to another vessel.

It therefore combines the advantages of the conical glass and urinometer-tube in one vessel.

Quantity of Urine. It is very important in all cases to know the quantity of urine passed in twenty-four hours. The most minute examination often fails to show any fact of importance in the investigation of a case, in consequence of the quantity of urine passed not having been measured. The practitioner in many cases desires to know the general amount of compounds resulting from the disintegration of tissues which are formed in the course of a given time, and this knowledge cannot be gained unless the urine be carefully measured. This is the more necessary, as the amount varies so much even in healthy persons. The temperature of the air, and the amount of moisture present in it; the state of the skin and mucous surfaces generally; the activity of the functions of respiration and circulation; the amount of exercise; the quantity and nature of the food, and, of course, the amount of fluid taken,—are some of the circumstances which affect the *quantity* of the urine passed. In health, it may be said to vary from fifteen or twenty to fifty or sixty ounces. Dr. Thudichum, in some experiments carried on for from fifty to seventy days, in the case of two individuals, finds the average amount to be from sixty to sixty-eight ounces in the twenty-four hours. The experiments were performed during the months of November, December, January, and February. In round numbers, the proportion in health may be estimated at from twenty to sixty ounces; and a greater quantity is passed in the winter than during the summer months.

Colour of Urine. Urine from the same person varies much in colour at different times, and specimens taken from a number of persons in a state of health exhibit the greatest variation in tint. Nevertheless, important information is often gained by observing the colour of urine. In some cases, from the colour, we are led to suspect the presence of certain substances dissolved in the fluid; in others, we may feel sure that

certain morbid constituents are not present. The colour of the urine, as well as many other characters, seems to be affected by the period of the day, the nature of the diet, the state of the respiratory process, changes of temperature, and many other circumstances. Healthy urine varies from a pale straw colour to a brownish yellow tint. In disease, it may be perfectly colourless, of a natural colour, bright yellow, pinkish brown, of a smoky appearance, blood-red, or even dark blue. What we learn from these differences in colour will appear when we come to consider the characters of the urine in disease. Urinary deposits also vary much in colour: they may be white, pink, red, pale or dark brown, blue or black. The nature of the colouring matters of urine has been carefully investigated by Heller, who obtained a yellow colouring matter, *uroxanthine*. This can be decomposed into a red colouring matter, *urrhodine;* and a blue substance, *uroglaucine*. The former has the same composition as indigo red; the latter, as indigo blue. Uroglaucine may be obtained from all specimens of urine, and, in disease, sometimes forms a visible blue deposit. Indigo blue has nearly the same chemical composition as hæmatine: it is doubtless formed from it. Leucine, which has also been met with many times in urine, is another substance which may be produced in the formation of this blue deposit of indigo. The yellow colouring matter of healthy urine was termed by F. Simon of Berlin, *hæmaphæin*. The presence of a substance in the urine from which indigo can be obtained must now be regarded as a settled fact; and it is probable that the blue deposit observed in certain instances, and referred to by different authors, was indigo blue, formed by the decomposition of uroxanthine.* Dr. Hassall has published some interesting cases, and has very carefully analysed the deposit.† I can fully confirm his statements, as I have recently

* See note on Heller's observations upon the colouring matters of urine, in Dr. Thudichum's "Treatise on the Pathology of the Urine," p. 326.

† Philosophical Transactions, 1854, p. 297; Proceedings of the Royal Society, June 16th, 1853.

had an opportunity of examining a specimen of urine with blue deposit, which was sent to me by my friend Dr. Eade of Norwich.* *Uroërythrine* is another colouring matter described by Simon, and always associated with uric acid and urate of soda. This substance is probably the same as *purpurine*, described by Dr. Golding Bird. It has been analysed by Scherer, who finds that it contains about 65 per cent. of carbon. It would seem that, when the elimination of substances from the liver, rich in carbon, is interfered with, an increased quantity of this substance is excreted in the urine. Dr. Harley finds that the colouring matter of healthy urine contains a notable quantity of iron, like the hæmatine of the blood; and he gives to it the name of urohæmatine. Prout believed that the colouring matter of urine was due to the presence of a sort of resin; and Dr. Harley has lately isolated a resinous substance, which possesses many characters in common with the resin derived from certain plants, and closely resembles draconine, which is obtained from dragon's blood, the exudation from the stem of one of the resin-bearing palms.

The relation of the colouring matters of the urine to those of the bile has been dwelt upon, and Berzelius long ago drew attention to the resemblance of the latter to the chlorophyll of plants. Certain chemical reagents cause the same change in both these colouring matters. A red colouring material is not unfrequently seen in the cells in the central part of the lobules of the liver, and Dr. Bence Jones met with a gall-stone of a brick-red colour. There is much reason for believing that the formation of these colouring matters is connected with the disintegration of blood-corpuscles, and the quantity formed and the intensity of the colour probably depend upon the activity of the oxidising processes going on in the organism; but the whole question of the production of colouring matter in the living body is still involved in great obscurity. The separation of a substance from the urine, from which indigo blue and in-

* This case will be published in the "Archives of Medicine," vol. i.

digo red may be prepared, must be regarded as a fact of the greatest interest; and further experiments on this subject are likely to lead to important results in connexion with the development of organic colouring matters.

Smell of Urine. From the smell of the urine, in some instances, the practitioner may gain useful information. Healthy urine has a peculiar and very characteristic smell, which has been described as aromatic, but well known to all: it probably depends upon the presence of certain organic acids. In disease, the specimen may be highly *pungent*, from the presence of *carbonate of ammonia*, which is produced by the decomposition of the urea excited by some animal ferment, especially by mucus of the bladder in a state of incipient decomposition. In other instances, it may have the smell of healthy urine, but the odour very much more intense. Sulphuretted hydrogen may be evolved from it. The smell of the urine is affected by many articles of food, such as asparagus, garlic, and cubebs. Turpentine, even if inhaled, causes the urine to evolve an odour something like the smell of violets.

Clearness or Turbidity. Healthy urine is perfectly clear and transparent; but, after it has been allowed to stand for a short time, a very faint, flocculent, bulky deposit collects towards the lower part of the vessel. This cloud consists of a little mucus, with imperfectly formed epithelial cells from the mucous membrane, and epithelial *débris*.

In disease, the urine may be opaque from the presence of different substances held in suspension. Urate of soda is the most frequent cause of this opacity, in which case the colour of the mass is generally of a dirty yellow, or brownish, resembling peas-soup. Very rarely it results from fatty matter in a minute state of division, and the urine has the appearance of milk. This occurs in cases of *chylous urine*. In these instances, the turbidity still continues after the urine has been allowed to stand still for some time; but generally the opacity of a specimen depends upon the presence of a deposit tempo-

rarily suspended in it from agitation, but which collects at the bottom of the vessel after a time, forming a visible deposit, leaving a perfectly clear fluid above it.

Consistence. Healthy urine is perfectly limpid, like water, and can be readily made to drop from a tube. In disease, however, the urine may be *slightly viscid*, or so *thick* and *glairy* that it may be drawn up at the end of a rod like a thread, and cannot be made to drop at all. It may be *semi-fluid;* and in rare instances, although passed perfectly fluid, it has afterwards assumed the form of a thick *firm jelly*, so that the vessel containing it might be inverted without its escape. Such specimens have been met with, associated with a milk-like appearance, in cases of *chylous urine*.

Deposit. The only deposit which urine in health contains is the faint unimportant mucus-cloud before referred to. All the constituents removed from the organism in this excretion, in health, escape in a perfectly soluble form; but when the healthy physiological changes are in any way interfered with, some of these constituents are produced in abnormal quantity, and are deposited, in an insoluble form, either at the time the urine is secreted, while it remains in the bladder, or at a variable interval of time after it has been passed. The deposit may be soluble in the warm fluid precipitated as soon as it becomes cold, or its deposition may be due to certain chemical decompositions occurring in the fluid.

The presence of a visible deposit in urine is, in all instances, to be regarded as *abnormal*. The nature and import of urinary deposits will engage much of our attention in the present course of lectures. I shall describe the different forms of deposit, and the mode of collecting them for examination, in a subsequent lecture.

Specific Gravity. By ascertaining the specific gravity of a specimen of urine, we are enabled to form a rough estimate of the quantity of solid matter dissolved in the fluid; and, by measuring the entire quantity of urine passed in the twenty-

four hours, we have data for judging approximately of the quantity of solid material removed from the organism in this secretion in twenty-four hours.

The specific gravity of healthy urine may be considered to be about 1015, and the quantity of solid matter passed in the twenty-four hours at from 800 to 1000 grains. It has been considered sufficient to calculate the quantity of solid matter from the specific gravity, by multiplying the number over 1000 indicating the specific gravity, by about 2·5. The result will give an approximation to the quantity of solid matter in 1000 grains of urine. This calculation is by no means correct, and is useless in careful investigations. Its inexact nature is shown by the fact that three very different numbers have been proposed, namely, 2·58, 2·33, and 1·65. When it is considered how widely different the composition of the solid matter may be in various specimens of healthy urine, it is obvious that results obtained in this manner must often be very wide of the truth. Take, for example, *albumen* and *common salt*. A fluid containing 136·4 grains of the former in 1000 grains will have a specific gravity of 1030; while one containing only 80.0 grains of common salt in the same quantity will have a specific gravity of 1064. This clearly shows that any attempt to *calculate* the quantity of solid matter in an animal fluid cannot be very exact. In investigations, therefore, where any approach to accuracy is required, we must evaporate a given quantity of urine (1000 grains) to dryness, at a low even temperature, and weigh the solid matter. In practice, this operation takes some time; and physicians are compelled, as a general rule, to be content with taking the specific gravity. In many cases, the information gained by this simple operation is very important. Thus the urine may be not more than 1002 or 1003—a condition commonly met with in hysteria. A patient may be continually passing urine of specific gravity 1010 to 1012, which is commonly the case with albuminous urine passed by patients suffering from certain chronic kidney diseases. Urine con-

taining a very large quantity of urea, so much that crystals of the nitrate of urea are formed upon the addition of nitric acid (*excess of urea*), usually reaches 1030 or a little higher; and, in cases of confirmed diabetes, where very large quantities of sugar constantly escape from the organism, the urine has a specific gravity of 1035-1040, or even higher.

Methods of taking the Specific Gravity. The specific gravity of a fluid is obtained most correctly by ascertaining the weight of equal bulks of the fluid to be examined and distilled water respectively. For this purpose, a small bottle, with a tubular stopper, holding exactly 1000 or 500 grains of distilled water, at a temperature of 60°, is the most convenient form of apparatus. All that is necessary is to fill the bottle carefully with the urine, wipe it dry, and then weigh it, after having counterpoised the bottle. The number of grains which the fluid weighs is the specific gravity in the case of the 1000-grain bottle, double the weight for the 500-grain bottle, four times the weight for a bottle holding 250 grains, and so on in like proportion.

This method, although perfectly exact, and readily performed where a good balance is at hand, is nevertheless too tedious and troublesome for the practitioner in a general way, and, in the sick-wards, a much simpler, though less correct method, is usually resorted to. The specific gravity is obtained by a small hydrometer, usually termed a *urinometer*. The form of this instrument, and the mode of using it, are well known; but there are one or two points in its construction and management which it may be well for me to refer to. As sold, these instruments are often nearly useless, in consequence of the carelessness displayed in their manufacture. Out of twenty instruments, I have found several differing as much as ten degrees from each other. If the stem of many urinometers be examined, it will be found that all the degrees marked upon it are equal, which clearly ought not to be the case; for when fluids of low specific gravity are operated on, a

very small portion of the stem remains above the surface of the liquid, while the reverse holds with respect to liquids of great density. In the latter case, there is, of course, a much greater weight of stem above the liquid, tending to force the instrument lower in the fluid than in the former. Allowance must also be made for the fact that the fluid becomes denser as we pass from the upper to the lower strata.* The tendency of the instrument to indicate a higher density than the real one renders it necessary that the degrees should decrease in length from the upper towards the lower part of the stem. The practitioner should carefully examine his urinometer, to see that there is this difference in the degrees; and, if not, it should be changed. I strongly recommend every one to test the urinometer by immersing it in fluids, the specific gravity of which has been ascertained by the bottle, or by a well made and previously corrected urinometer. If the degrees are incorrect, the observer can always bear in mind the amount of error, and allow for it in taking the specific gravity of different specimens of urine. The vessel which is employed for immersing the urinometer in should not be too narrow, in case the bulb should rub against the sides, when it becomes difficult to ascertain the real density. The diameter of the glass vessel should be rather more than a quarter of an inch over that of the widest part of the bulb of the urinometer. The glass delineated in Figure 1 is a very convenient form.

Another method of taking the specific gravity, which is sometimes followed, consists in having a number of small glass bulbs, with the density of the fluids in which they neither sink nor swim marked upon them. By placing one after another into the urine, one is found which remains just beneath the surface, and the number upon it indicates the specific gravity of the fluid.

Reaction. You may easily ascertain the reaction of urine by

* This error has been corrected by Mr. Ackland, of Messrs. Horne and Thornthwaite's, where accurately graduated instruments may be obtained.

the use of litmus-paper, which is prepared by soaking a thin but firm smooth paper in an infusion of litmus. It is desirable not to use blotting paper, or any spongy form of paper, for this purpose. Urine, having an *acid* reaction, immediately reddens this blue paper. The *alkaline* reaction of urine is ascertained by the use of *reddened litmus-paper*, prepared by adding a very small quantity of dilute acid to the infusion of litmus. An alkali always restores the *blue* colour of this reddened paper. If no change occurs when the urine is tested with both kinds of paper, the reaction of the specimen is *neutral*.

Acid Urine. The cause of the acid reaction of urine is obscure, and probably is not always of the same nature. Sometimes the reaction may depend upon carbonic acid, which is present in greater or less proportion in all the animal fluids. In this case, the blue colour of the paper is restored by gently warming it after it has been changed by the acid. A fixed acid reaction may be due to the presence of an acid phosphate of soda—a salt which exhibits an acid reaction, without the presence of any free acid. This salt may be formed by the action of uric acid upon common rhombic phosphate of soda. If I add a little uric acid to this solution of common rhombic phosphate of soda, the mixture still exhibits the characteristic alkaline reaction of the salt; but now, when heat is applied, decomposition occurs; the uric acid disappears, and combines with one equivalent of the soda to form urate of soda; and an acid phosphate of soda is produced. The acid reaction of urine, however, cannot always be explained in this manner; and it is probable that traces of free organic acids are often present. Lehmann has found both free lactic and free hippuric acids in some specimens of urine. Lately, Hallwachs has shown that a large amount of hippuric acid salts exists in healthy human urine.

Many specimens of urine which are slightly acid when passed from the organism, become more strongly so after

standing for some days, and crystals of uric acid are deposited. The acid reaction may remain for weeks or even months, but usually the acidity gradually diminishes, and the specimen at last becomes alkaline from the presence of carbonate of ammonia formed in consequence of the decomposition of the urea. The beautiful researches of Scherer have proved that the gradually increasing intensity of the acid reaction, and the deposition of uric acid, were due to a process resembling fermentation, which was excited by the presence of a small quantity of mucus.

The intensity of the acid reaction of urine in health is continually undergoing change at different periods of the day. Dr. Owen Rees* and Dr. Bence Jones have made numerous highly interesting observations, which prove that the acidity of the urine alternates with that of the gastric juice. When the largest quantity of acid is being set free from the stomach, the acidity of the urine is at its minimum; and when the secretion of gastric juice is diminished, the urine exhibits a most strongly acid reaction. The urine passed just before each meal, or a long time after taking food, is intensely acid, while that which is secreted during the digestive process, for about three hours after a meal, is very slightly so, and in many instances it is decidedly alkaline. It is especially important to bear in mind the existence of these variations in the acidity of the urine in a state of health, and not to refer the intensely acid reaction of urine secreted while no food is taken, to a morbid process requiring the exhibition of large doses of alkalies (*On Animal Chemistry*, by H. Bence Jones, M.A., M.D., F.R.S.). Dr. Beneke has made upwards of one hundred experiments upon healthy and diseased persons without being able to confirm Dr. Bence Jones' observations. In only one case did he find the urine alkaline after meals. Sometimes the acidity was less, but this was not invariably the case. Nevertheless, he admits that the

* Lettsomian Lectures (Med. Gazette, vol. xlviii, 1851). "The degree of the acidity of the urine may to a certain extent be regarded as a measure of the acidity of the stomach."

acidity of the whole amount of urine passed varied considerably, although he could not discover the cause. It seemed to be independent of the quantity passed, and was not affected by exercise or food (*Archiv des Vereins für gemeinschaftliche Arbeiten zur Förderung der wissenschaftlichen Heilkunde*, 1 Band. 3 Heft.). Vogel's researches confirm the former results, inasmuch as he found that urine passed during the night was more acid than that secreted during the digestive process. Dr. Bence Jones's results are also confirmed by some recent researches of Mr. Wm. Roberts. There can be little doubt of the truth of the facts stated, but there are several ways in which they may be explained.

The intensity of the acid reaction is readily determined by ascertaining how much of a graduated solution of carbonate of soda is required to neutralise the acid in a given quantity of urine.

Alkaline Urine. The alkaline reaction of a specimen of urine may be due to the existence of carbonate of ammonia, in which case the blue colour produced by testing it with reddened litmus is destroyed by the application of a gentle heat (*volatile alkali*); or it may depend upon the presence of an alkaline carbonate, as carbonate of soda, or a neutral salt having an alkaline reaction, like common phosphate of soda, in which cases the application of heat does not restore the red colour of the litmus paper (*fixed alkali*).

Volatile Alkali. The development of carbonate of ammonia in urine depends upon the decomposition of the urea by the action of the mucus or some animal matter, which acts the part of a ferment. In some diseases of the mucous membrane of the bladder, and in cases of paraplegia, where the muscular coat of the organ is paralysed, and consequently the secretion is retained for a long time, this change is very liable to occur, and gives rise to pain and great distress, which are much relieved by washing out the bladder thoroughly with tepid water. A mere trace of urine which has undergone this change is capable

of exciting a similar decomposition in a very large quantity. It is important to notice that if pus be present in such urine, it becomes converted into a viscid glairy mass, which is removed from the bladder with the greatest difficulty. This action of the volatile alkali on the pus precisely accords with that which occurs if ordinary liquor potassæ be added to a specimen of pure pus out of the body. Pus thus rendered glairy, forming a viscid adhesive mass at the bottom of the vessel containing the urine, is usually called *mucus*, but, as I have said, it really consists of altered pus. If this action on the pus only occurs after the urine has left the bladder, it is unimportant, but when it occurs before its expulsion, it is always necessary to interfere, and if the change cannot be entirely prevented, owing to the existence of certain mechanical impediments to the escape of the urine, we must try to render the urine acid, and thus prevent its occurrence, by giving very large and frequently repeated doses of nitric acid, unless this treatment is contra-indicated, as in certain cases which I shall have occasion presently to refer to.

Whatever causes prolonged retention of the urine in the bladder, in the ureter, or pelvis of the kidney, will excite this change, and as a consequence, roughening and ulceration of the mucous membrane ensue, with the precipitation of phosphate of lime and ammoniaco-magnesian phosphate. More pus is formed, which effects the decomposition of the urea and aggravates the mischief already produced, and unless relief be afforded, complete disorganisation of the mucous membrane results. Volatile alkali is never detected in healthy urine.

Fixed alkali. Urine, however, often exhibits an alkaline reaction due to the presence of an alkali which is not volatile by heat, and this reaction is often to be met with in a state of health. When an alkaline carbonate is detected in the urine, it usually results from the decomposition of salts of certain organic acids in the organism. Salts of tartaric, racemic, citric, and under some circumstances, those of oxalic and

acetic acids, become resolved into carbonates in their passage through the organism, just as by the influence of a red heat, they are converted into carbonates out of the body. The urine may always be rendered alkaline, and very quickly so, by giving such salts in sufficient quantity; and their administration is of great advantage in cases where benefit is likely to be derived from alkalies, especially where strong alkalies do not agree with the digestive organs. I believe that in many cases the alkali thus formed in the organism exerts a more beneficial influence than the exhibition of alkalies or their carbonates. The value of the juice of oranges and lemons in various conditions is to be attributed to this change.

If the alkaline reaction of the urine is due to the presence of carbonate of ammonia crystals of triple phosphate (*Illustrations*, pl. ix, fig. 1; xxi, figs. 1, 3), and a deposit of phosphate of lime in a granular state, or in the form of globules or minute dumb-bells will be present; if, on the other hand, it depends upon fixed alkali, only the latter deposit without the crystals will be detected.

In many cases, the alkaline reaction of urine is attributed by Dr. G. O. Rees to the increased quantity of alkaline fluid poured out by the coats of the bladder when exposed to increased irritation from the contact of urine which was secreted *highly acid*. This is especially so in certain cases of injury to the spine, when the mucous membrane is less able to resist the action of irritating fluids than in health. In such cases, therefore, the urine will be rendered less alkaline by giving alkalies, as the secretion will be less irritating and less acid as it passes over the mucous membrane of the bladder.*

Before resorting to a minute examination of a specimen of urine, it is important to ascertain the *quantity* passed in twenty-four hours, to notice its *colour*, *smell*, *consistence*, *clearness* or *turbidity*, and the presence or absence of a *deposit*, and to ascertain its *specific gravity* and *reaction*.

* Lettsomian Lectures, 1851.

LECTURE II.

Healthy Urine. I. VOLATILE CONSTITUENTS. II. ORGANIC CONSTITUENTS. III. INORGANIC CONSTITUENTS.—VOLATILE CONSTITUENTS: *Water; Carbonic Acid; Peculiar Organic Acids; Ammonia and Ammoniacal Salts.*—ORGANIC CONSTITUENTS: *Urea; Quantity; Characters; Circumstances affecting the Formation of Urea; Origin: Creatine: Creatinine: Guanine: Sarcine: Inosite: Uric Acid; Quantity; Detection; Mode of Formation: Urates: Hippuric Acid: Extractive Matters: Mucus: Lactic Acid and Lactates.*

GENTLEMEN,—After having discussed the general characters of healthy urine, we may now pass on to consider the characters of the different substances found in this excretion. It is convenient to divide them into three classes, viz.:

I. VOLATILE CONSTITUENTS;
II. ORGANIC CONSTITUENTS;
III. INORGANIC CONSTITUENTS.

The first class includes those substances which are volatilised at the temperature of a steam-bath (212° or less). The most important of these are, *water*, *carbonic acid*, and *certain ammoniacal salts*.

The second class contains those organic constituents which are not volatilised at a temperature of 212°, but which are decomposed at a red heat. The most important of these are, *urea*, *uric* or *lithic acid*, *hippuric acid*, with *urates* and *hippurates*, *lactic acid and lactates*, *mucus* from the urinary mucous membrane, *creatine*, *creatinine*, and various indeterminate uncrystallisable substances included under the head of *extractive matters*. The *colouring matters* before described,

and perhaps traces of *leucine*, *tyrosine*, and one or two other less important organic matters, would be included in this class.

In the third class are found various *saline matters* which remain fixed after the organic matter has been destroyed by a red heat, and the carbon which results removed by prolonged exposure to a dull red heat in contact with the air. These inorganic constituents consist principally of *chlorine*, *sulphuric* and *phosphoric acids*, and, in some cases, *nitric acid*, in combination with *sodium*, *potash*, *soda*, *lime*, *magnesia*, *iron*, and sometimes *alumina*, with traces of *silica*.

I.—Volatile Constituents.

Water. Healthy urine contains from 940 to 960 grains, or even more, in 1,000. The proportion of water is much influenced by various circumstances, especially by the quantity taken in the food, the activity of the skin, and the presence of various substances which influence the chemical changes going on in the tissues, or affect the secreting action of the kidneys. The mode of estimating the proportion of water has been before alluded to. At first this would be supposed to be a very simple matter, but in practice it is found to be one of the most difficult operations in analysis, because many of the organic constituents of urine are prone to undergo changes at a very moderate heat, and even at the temperature of the air, if the concentration is effected too slowly. Practically, it is the best plan to concentrate the urine at a temperature of 100°, and then continue the evaporation *in vacuo* over sulphuric acid until the residue ceases to lose weight.

Carbonic Acid is held in solution in fresh urine: indeed, traces may be detected in all the animal fluids. Its presence may be shown by passing some pure hydrogen gas through urine. After the gas has traversed the urine, it should be conducted into pure lime water, which will become turbid if there

be an appreciable quantity of carbonic acid present. This experiment is founded upon the fact that, if one gas be passed through a solution of another gas, the latter will be displaced by it. By distillation, also, the presence of carbonic acid may be shown; but, in this process, great care must be taken to prevent the production of carbonate of ammonia, which would, of course, cause a precipitation of carbonate in lime or baryta water. The fluid may be made to boil at a temperature of 120, if the air be exhausted.

Peculiar Organic Acids. Besides carbonic acid, urine contains, according to the observations of Städeler, a peculiar acid to which the name of *damaluric acid* has been given. It has a powerful odour; but little is yet known of the circumstances under which this volatile acid occurs. *Phenylic* or *carbolic acid*, usually known as *creasote*, has also been detected in urine; but these acids, with the *damolic* and *taurylic acids*, as they occur in urine, have as yet been so little studied, that we know nothing of any practical importance connected with them.

Ammonia and Ammoniacal Salts. Another volatile constituent of urine is *ammonia*. The presence of this substance in healthy urine has been doubted by many; but Heintz has shown that the addition of chloride of platinum to fresh urine causes a precipitate which consists of the potassio-chloride of platinum, with a certain quantity of the ammonio-chloride of platinum; the amount of the latter being estimated by determining the quantity of the potassio-chloride in a separate experiment. Ammonia exists as urate and lactate; it is also found in combination with phosphoric acid and soda, and with phosphoric acid and magnesia. Chloride of ammonium is also present.

Ammonia is likewise given off during the decomposition of several of the organic constituents of the urine by heat, as indeed it is from many other nitrogenous organic substances. Thus, if a portion of the solid residue of urine be exposed to a

red heat in a small glass tube, much very offensive vapour will be given off, and a carbonaceous residue will remain in the tube. If a piece of reddened litmus or turmeric paper, moistened with distilled water, be applied to the mouth of the tube as soon as it is heated, the blue colour of the former will be restored, and the latter will assume a dark brown tint—reactions which indicate the existence of volatile alkali or ammonia, which arises from the decomposition of the nitrogenous matters.

II.—Organic Constituents of Healthy Urine.

Many of the constituents of healthy urine may be obtained in a crystalline form by allowing a few drops to evaporate, at a moderate temperature (about 140°), upon a glass slide, or in a shallow oval glass cell. In this manner, crystals of urea, urate of soda, chloride of sodium crystallised in cubes and octohedra, phosphates, and sulphates, may be readily obtained. The observer should make himself familiar with the appearance of these crystals. (*Illustrations of Urine*, etc.; Urine, Plate I.)

The quantity of the organic constituents varies very much, as would be supposed. In healthy urine, about three-fourths of the solid matter consists of organic substances, and there may be found from 12 or 14, to 45 or 50 grains in 1,000 grains of urine. The mode of estimating the amount of solids has been already referred to. The quantity of the organic constituents is easily obtained by burning a weighed portion of the solid matter, and by subtracting the quantity of saline residue which remains. The result is the required quantity of organic constituents.

Urea. The most important of the organic constituents of urine is urea. It is a crystalline substance, very soluble in hot water, and in four or five parts of cold water, soluble in alcohol, but insoluble in pure ether, deliquescent, readily crystallised if pure, but the presence of some organic constituents interferes

with its crystallisation. However, good crystals of urea may often be obtained by simply evaporating a specimen of urine upon a glass slide, at a moderate temperature. Urea has a cool saline taste, is perfectly colourless when pure, but has a very strong affinity for the colouring matter of urine. In order to obtain perfectly colourless urea from urine, it is necessary to expose it to the prolonged action of animal charcoal in a diluted state.

Quantity. Urine in health contains from 12 or 15 to 30 or 40 parts of urea per 1,000; and as much as from 400 to 600 grains of solid urea are excreted from the body of a strong healthy man in twenty-four hours. The solid matter of healthy urine contains half its weight of pure urea.

Detection. The presence of urea is very easily detected, if the solution be moderately strong. Here I have some urine which has been slightly concentrated by evaporation, and afterwards allowed to cool. Upon the addition of a few drops of strong nitric acid, a number of beautiful sparkling crystalline lamellæ make their appearance. These are not very soluble in water, and are easily recognised by their microscopical characters. (*Illustrations of Urine*, Plate III.) In this manner nitrate of urea is prepared.

If, instead of adding nitric acid to the concentrated urine, I were to add a concentrated solution of oxalic acid, I should obtain numerous crystals of oxalate of urea, also a very insoluble salt, and, like the nitrate, crystallising in rhomboidal plates; but the crystals are more perfectly formed, and the inclination of the angles is different. (*Illustrations of Urine*, Plate IV.)

A solution of nitrate of mercury also forms a precipitate with urea; but, in order to apply this test, all the chloride of sodium and phosphates must be removed. Liebig has proposed a most simple and highly efficacious plan for estimating the quantity of urea by ascertaining the amount of a solution of pernitrate of mercury, of known strength, which is required to throw down the whole of the urea in a given volume of urine.

urine; an oxalate or nitrate is first prepared, purified by being recrystallised, dissolved in water, and heated for some time in contact with pure animal charcoal. When the solution is colourless, it is decomposed with chalk or carbonate of barytes. The solution of urea is concentrated, so that crystals may form. The pure crystals are very deliquescent; but, with care, they may be dried and preserved for any length of time, if carefully excluded from the air. They form beautiful microscopic objects.

Rich in nitrogen, very soluble in water, readily diffused through large quantities of fluid, and possessing considerable power of permeating animal membrane, urea may be regarded as the principal product resulting from the disintegration of nitrogenous tissues, and as one of the most important excrementitious substances from the animal organism. Not only is urea derived from the products resulting from the disintegration of muscular fibre, but any excess of albuminous materials taken in the food is removed from the body chiefly in the form of urea.

Circumstances affecting the Formation of Urea. The quantity and nature of the food, and all circumstances which affect the nutrition and repair of the tissues, will exert an influence upon the quantity of urea formed in a given time. A liberal diet, rich in albuminous substances, and active exercise, combined with a healthy state of the organs of respiration and circulation, cause the formation of a large quantity of urea; while indolent habits, a diet rich in carbon and poor in nitrogen, insufficient food of any kind, an unhealthy state of the lungs and circulatory organs, and an imperfect supply of good air, will diminish the proportion formed. I need hardly say that a greater quantity of urea is formed during the day than during sleep; by strong muscular persons, than by weak ones; by men than by women; in winter, when a small quantity of excrementitious substances are removed by the skin, than in summer, when the perspiration is abundant.

This process for estimating the quantity of urea, as well as other constituents of the urine, *volumetrically*, will engage our attention in a future lecture.

Characters. Urea crystallises in four-sided prisms, which seem to be composed of a number of acicular crystals. (*Illustrations of Urine*, etc., Pl. II, p. 56.) It melts at 248°, and is decomposed at a higher temperature; cyanate of ammonia and carbonate of ammonia being among the products of the decomposition. It is not decomposed by being boiled in pure water, but mere traces of putrescent animal substances excite rapid decomposition even in the cold. Yeast also exerts the same effect; and mucus and pus produce this decomposition very rapidly, as already remarked under the head of "alkaline urine". The rapid evolution of carbonate of ammonia from urine which has been placed in a dirty vessel, is explained in the same manner.

It is curious that urea causes common salt, which, under ordinary circumstances, crystallises in cubes, to crystallise in octohedra; and chloride of ammonium, which crystallises in octohedra, to crystallise in cubes.

In the laboratory, urea may be formed artificially. By allowing cyanate of ammonia to evaporate to dryness, it becomes converted into urea, in which neither cyanic acid nor ammonia can be detected. Urea is one of the products formed by the action of peroxide of lead on uric acid, and it is also produced by the action of alkalies upon alloxan and creatine. Béchamp stated that he had obtained urea directly from the action of oxidising substances on protein compounds, as permanganate of potash upon albumen. This experiment has been many times tried in my laboratory without success, and several chemists have failed to confirm Béchamp's results; so that we may consider that, up to the present time, no one has succeeded in producing urea directly from the tissues, or from albuminous substances.

Suppose I wish to obtain a specimen of pure urea from

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In all probability, urea is formed in the organism by the oxidation of uric acid. The latter substance, if the oxidating processes in the body are active, becomes resolved in great measure into urea and carbonic acid; but if, on the other hand, these processes are less active than they should be, the uric acid in the urine is increased in quantity; a certain quantity of oxalic acid, and other substances of a lower degree of oxidation than urea, seem to be produced, instead of nearly the whole of the uric acid being resolved into this soluble substance. Wöhler and Frerichs have shown that, if uric acid be taken at night, oxalate of lime is found in the morning urine; and Neubauer found that, when rabbits were made to take a considerable quantity of uric acid with their food, the urea in their urine increased from 1·34 to 4 grammes (from 20·67 to 61·72 grains). Large quantities of fluids cause an increase in the proportion of urea formed in the organism. A dilute state of the solids is favourable to their oxidation; and in certain conditions, where these changes are but imperfectly carried on—and in consequence uric acid accumulates in the blood, or at most is resolved into oxalic acid—the further oxidation is promoted by the administration of increased quantity of fluid, especially of fluids containing alkalies which not only increase the activity of the changes, but effect the solution of the insoluble uric acid and urates. Hence the benefit of alkaline waters, baths, moderate exercise, and plenty of good air, in gout and other conditions in which much more uric acid is formed than can be, under ordinary circumstances, converted into urea.

The quantity of urea excreted is also increased by common salt (Bischoff). It is probable that not only does chloride of sodium, so to say, filter through the different tissues, like other saline substances, and thus drive out certain materials which are contained in their interstices; but that it also facilitates the occurrence of chemical change in the body, and directly influences the quantity of urea formed. The importance of chloride of sodium to cell-growth and the development of

different textures, and its value in nutrition, are well known. (On the Chlorides in Pneumonia, *Med.-Chir. Trans.*, vol. xxxv.) The beneficial effect of alkalies in different cases is generally acknowledged; and it is probable that this is in part to be explained by the influence they have been proved to possess in promoting chemical change in the body, and especially in favouring the oxidation of albuminous substances. Dr. Parkes has shown conclusively, in an elaborate series of experiments, that liquor potassæ exerts a direct influence of this kind. ("On the Action of Liquor Potassæ on the Urine in Health", *British and Foreign Medico-Chirurgical Review*, vol. xiv, p. 258, January 1853.) The per centage of solids in the urine is increased, the urea is increased, and the proportion of sulphates augmented, owing to the oxidation of the sulphur of albuminous tissues. Franz Simon long ago showed that the sulphates were always increased whenever an increased proportion of urea is formed; and the more recent researches of Dr. Bence Jones lead to the same conclusion. In Dr. Parkes's experiments, the acidity of the urine was hardly affected by the liquor potassæ; and the whole of the potash taken was entirely excreted in the urine, in the form of sulphate, in a very short time; if taken on an empty stomach, in from thirty to ninety minutes. Such facts assist in the most important degree in elucidating some of the most complicated chemical changes going on in the organism, and afford valuable information as to the nature of various morbid changes, as well as suggest the means by which these may be modified or counteracted. For these reasons, I have thought it desirable to dwell upon them rather at length.

On the other hand, both the solids and fluids of the urine are diminished by alcohol; so also is the proportion of carbonic acid exhaled. Tea causes a diminution both in the quantity of urine and fæces, as the beautiful researches of Dr. Böcker have conclusively proved. (*Medico-Chirurgical Review*, vol. xiv.) Coffee exerts a similar effect, which seems to be due, not to the

caffein, but to the empyreumatic oil which it contains, according to Julius Lehmann. These substances, tea, coffee, and alcohol, in moderate quantity, affect the disintegration of tissue, and directly diminish the quantity of the excrementitious substances formed in the process. Supposing the food to be insufficient, the loss of weight which must necessarily take place in the body would be lessened; and they may, therefore, be regarded as advantageous, not only in economising the food, but in limiting to some extent the waste of the albuminous tissues.

In disease, the proportion of urea excreted varies very greatly; but upon this head I shall have more to say in a future lecture.

Origin. Urea is not formed in the kidneys, but exists in the blood, and is merely selected or separated from this fluid by the cells of the uriniferous tubes. It is with difficulty detected in healthy blood, because it is prevented from accumulating in that fluid in sufficient quantity by the selective power of the renal epithelium.* If, however, the secreting action of the kidneys be impaired by disease, or if the blood be prevented from flowing through them, the urea will accumulate in the blood to a considerable extent, interfering with the function of other organs, especially the brain; and may in many cases be very readily detected by chemical tests.

Under these circumstances, an incomplete removal of the urea will take place through other channels. It has been detected in the fluids of the intestinal canal, in vomited matters, in the saliva, tears, milk, bile, and sweat, in serous fluids in different localities, in the liquor amnii, and in the fluids of the eye.

Urea cannot always be detected in the muscles, but can be

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* Dr. Thudichum attributes the failures of observers to detect urea in the blood, to their precipitating the albumen by heat. If the blood be treated with strong alcohol, the urea is dissolved, and the albumen rendered insoluble at the same moment. The former can be detected in the alcoholic solution.

readily produced from several substances found in them; and it is therefore probable that, in the organism, urea forms the last of a series of compounds which results from the disintegration of the tissues. Removed from the body, very slight causes are capable of effecting its decomposition, and resolving it into ammonia and carbonic acid—substances of the highest importance to the growth of plants.

Creatine exists in small quantity in urine. Its presence in this secretion was discovered by Heintz. Dr. Thudichum has obtained from 3·45 to 6·32 grains of creatine from the urine of a healthy man in twenty-four hours. Creatine has a pungent taste, is very soluble in hot water, but requires about seventy-five parts of cold water for its solution. It is very slightly soluble in alcohol, and quite insoluble in ether. It crystallises in right rectangular prisms and rhomboidal crystals. (*Illustrations of Urine*, Pl. VII, Fig. 3.) By being boiled with baryta water, it is converted into urea and sarcosine; with strong acids, into creatinine.

Creatine may be obtained from urine by the following process, proposed by Liebig. Lime water and chloride of calcium are first added to the urine, which is then filtered and concentrated by evaporation, in order to remove most of the salts. The liquid from which the salts have been separated is decomposed with one-twenty-fourth of its weight of a syrupy solution of chloride of zinc. After the lapse of some days, a number of round granules make their appearance. These consist of chloride of zinc and creatinine, with which creatine is mixed. (*Illustrations of Urine*, Pl. VII, Figs. 1 and 2.) They are dissolved in hot water, and treated with hydrated oxide of lead until the reaction is alkaline. The oxide of zinc and chloride of lead are to be removed by filtration; and, after being decolorised by animal charcoal, the solution is evaporated to dryness. The residue is to be treated with boiling alcohol, which dissolves the creatinine very readily, but leaves the creatine, which may be recrystallised by solution in hot water.

Creatine is obtained from all kinds of lean meat, but exists in larger proportion in that of mammalia than in birds, reptiles, and fishes. Gregory obtained ·14 from 100 parts of bullocks' heart, ·08 in 100 parts of pigeons' flesh, and ·06 in the same quantity of the flesh of the skate. Although the flesh of fishes contains less creatine than that of the higher animals, it is more favourable for extraction. I obtained more than seventeen grains of creatine from two pounds of the flesh of the crocodile. The presence of creatine has been detected in the blood by Verdeil and Marcet. Traces of it have been discovered in the amniotic fluid.

Its existence in the juice of muscular tissue, and its presence in the urine, would lead to the conclusion that creatine was one of the nitrogenised products resulting from the disintegration of muscular tissue; and such a view of its nature is supported by the readiness with which it is decomposed into urea, creatinine, and sarcosine. It is found in greater quantity in muscles which have been in active exercise during life, than in those which have been quiescent. The heart yields a large quantity; and more is found in animals which have been hunted to death, than in those destroyed without being subjected to violent exercise. Creatine may, like urea, be regarded as an excrementitious substance.

Creatinine is also crystalline. The crystals take the form of right rectangular prisms, according to Robin and Verdeil. It has a strongly alkaline reaction, and is soluble in water. It is very soluble in warm alcohol. It combines with different acids to form salts. With chloride of zinc, a crystalline compound is formed, composed of roundish wart-like masses, made up of minute radiating crystals, which have been already referred to.

Creatinine is found in the urine in larger proportion than creatine, and must be considered as an excrementitious substance. It is not destroyed in the decomposition of urine, while the creatine undergoes conversion into creatinine. Dr.

Thudichum obtained as much as from five and a half, to nearly ten grains of creatinine from the urine of a healthy man in twenty-four hours.

Guanine, Sarcine, Inosite. Strahl and Lieberkühn have discovered a substance in urine which they considered to be xanthine, but which, from its behaviour with reagents, may probably be regarded as guanine. Strecker has detected in urine a substance closely resembling sarcine, found in muscular fibre; but its exact nature is at present doubtful. Inosite has been found in the urine of a man suffering from Bright's disease by Cloëtta, but it has not yet been detected in healthy urine.

Uric Acid. The organic constituent of the urine which ranks next in importance to urea is uric or lithic acid. In healthy urine, its presence cannot be detected, unless a small quantity of a stronger acid, as nitric or hydrochloric, be first added to decompose the soluble urates. After the mixture has been allowed to stand for some time, the uric acid separates in the form of small red crystalline grains, which adhere to the sides of the glass vessel. Upon microscopical examination, these are found sometimes to be composed of separate crystals, and sometimes of small stellate groups; the individual crystals varying in form from the lozenge-shape to that of an elongated crystal with sharply pointed extremities. (*Illustrations*, Pl. IV, Figs. 2, 3, 4, and 5.) Uric acid is a very weak acid, and is perfectly separated from its salts by acetic acid. It is soluble in solutions of alkaline lactates, acetates, carbonates, phosphates, and borates. Uric acid has the power of decomposing the alkaline phosphates. It takes a part of the base, forming a urate, and leaves an acid phosphate, as I mentioned when speaking of the acid reaction of urine. The colour of the crystals of uric acid which have been obtained from urine is derived from the proper colouring matters of the secretion, and must, therefore, be regarded as an impurity. It can easily be obtained perfectly pure and colourless; and, in three or four instances, I have observed perfectly colourless crystals of this

substance, which have separated spontaneously from urine holding in solution scarcely a trace of colouring matter.

Pure uric acid crystallises in the form of very thin rhomboidal laminæ; but the sides of the crystals, instead of being perfectly straight, are usually more or less curved. The angles, again, are often rounded, so that the crystal has an oval form. In Plate IV, Figs. 2 and 5, and Plate V, Fig. 7, of the *Illustrations*, some pure crystals of uric acid are represented. Some of these crystals were obtained by the addition of acid to the solution. Although uric acid may be perfectly pure, the crystals vary much in size and form. Experiments show what very slight variations in the conditions under which they are produced are sufficient to determine great alterations in the form of the crystal.

Quantity. Healthy urine contains from half a grain to a grain of uric acid in 1,000 grains of urine. The solid matter contains about 1·3 per cent. of this substance, and probably from five to eight grains are excreted by a healthy adult man in twenty-four hours. Dr. Thudichum gives the latter as the average quantity.

Detection. The chemical characters of uric acid are well marked.

1. If to a deposit consisting of uric acid, placed on a glass slide, a drop of nitric acid be added, a brisk effervescence ensues; and when the mixture is slowly evaporated over a lamp, a reddish residue is left. Upon the addition of a drop of ammonia, a rich purple tint is produced, owing to the formation of murexide, the so called purpurate of ammonia. This test is exceedingly delicate: it was first applied by Dr. Prout. One other substance possesses a similar reaction, and this is caffeine; but uric acid is at once distinguished from it by its microscopical characters.

2. The deposit suspected to contain uric acid or a urate may be dissolved in a drop of solution of potash, in which it is very soluble. Upon adding excess of acetic acid, and leaving the

mixture for some hours, small crystals of uric acid will form. These may be recognised by their microscopical characters.

3. Uric acid may be detected in animal fluids, when mere traces of this substance or of urates are present, by a plan proposed by Dr. Garrod. The fluid suspected to contain the urate is treated with a few drops of strong acetic acid (glacial acetic acid is best) in a watch-glass. A few filaments of tow or very thin silk are placed in the mixture, and the whole set aside under a glass shade, in a warm place, for twenty-four or forty-eight hours. Gradually uric acid crystals separate, and are deposited upon the filaments. Their characters may be recognised by microscopical examination. Some crystals of uric acid upon a hair are represented in Plate XXI, Fig. 6, of the *Illustrations.*

The quantity of uric acid is estimated by collecting the crystals separated by the addition of an acid, and weighing them after they have been carefully washed and dried. Dr. Thudichum recommends the use of nitric acid, because the uric acid is less soluble in it, and there is not so much tendency to the development of fungi as if hydrochloric be employed.

Mode of Formation. Uric acid is found in the urine of most carnivorous animals, and in that of young herbivora while sucking, and therefore feeding upon a diet rich in nitrogen. It is not found in the urine of the pachydermata, not even in that of the omnivorous pig. It is abundant in the urine of birds, and is found in that of many reptiles and insects. Uric acid exists in the blood, and is only *separated* from that fluid by the kidneys. Dr. Garrod has detected it in the blood of men in health, and in cases of gout in considerable quantity. In such instances, uric acid crystals may be separated from the fluid obtained from a blister, according to the plan I just described. It has been detected in the juice of the spleen in considerable quantity by Scherer, but Mr. Gray has failed to

confirm these observations. Cloëtta has found it in the pulmonary tissue of bullocks' lungs, associated with taurine, inosite, and leucine.

Uric acid is one of the products resulting from the disintegration of albuminous tissues. Prout held "that a very large proportion of the urate of ammonia found in the urine on common occasions appears to be developed from the imperfect albuminous matters formed during the assimilating processes". This is rendered probable by the researches of later observers, especially by those of Bidder and Schmidt. In the healthy organism, it is probable that the greater quantity of the uric acid formed is soon afterwards further oxidised and converted into other compounds, especially urea; but, in certain conditions of the system, these changes do not take place to the full extent, or a much larger proportion of uric acid is formed. In either case, this substance exists in largely increased quantity in the blood. It is deposited, in combination with soda and lime, in various structures. It may accumulate beneath the skin, so as to form large collections, which are familiar to us under the name of chalk-stones. It is curious that these depositions should take place in areolar tissue, in white fibrous tissue, and in connexion with cartilage. Perhaps this may be connected with the very slight vascularity of these tissues; and it must be borne in mind that the deposits usually occur at a time of life when they are fully developed, after which they probably undergo very slight changes, and the processes concerned in their decay and regeneration are slowly, and perhaps, in sedentary persons, very imperfectly carried on. All these circumstances would favour the separation of a slightly soluble substance from the blood, and its deposition in an insoluble state. Lehmann has shown that, after attacks of disturbed digestion, the proportion of uric acid in the urine becomes increased. Alcoholic liquors seem to have the same effect. In normal conditions of the system, the urine contains about 1 part of uric acid to 28 or 30 parts of urea; but, under

the circumstances just mentioned, the ratio becomes 1 to 23 or 26. This increased proportion of uric acid appears to be formed in consequence of the usual proportion not being converted into urea. In all cases where imperfect oxidation takes place in the organism, the quantity of uric acid excreted in the urine undergoes an increase. Alcohol causes a diminution in the quantity of carbonic acid exhaled; and, in such cases, an increased proportion of uric acid, urates, and usually oxalates, is found in the urine.

A highly nitrogenised diet, with insufficient exercise—confinement in ill-ventilated rooms—all circumstances interfering with the healthy action of the respiratory apparatus—or preventing the proper amount of blood being carried to the pulmonary surface, active exercise in confined air, etc.,—are conditions favourable to the formation of an increased quantity of uric acid and urates. The formation of urea and oxalic acid from uric acid in the organism, or artificially by the action of peroxide of lead, has been previously alluded to. Ranke has shown that, at a high temperature, in the presence of yeast and an alkali, uric acid also becomes converted into urea and oxalic acid.

Urates. Uric acid is separated from the blood by the kidneys, in the form of a urate, which is readily soluble in water. After its separation, however, this salt may soon undergo decomposition, and insoluble uric acid will be deposited. In the majority of cases, this decomposition does not take place until after the urine has left the bladder; but sometimes it occurs in the bladder itself. The causes of the precipitation of uric acid are well worthy of attentive study, as they are intimately connected with the formation of uric acid calculi. The quantity of urates in healthy urine is very small, but not unfrequently enough is present to form a very abundant deposit after the urine has been allowed to stand for some time. I propose to describe the characters, and allude to the composition, of these salts, when we consider the subject of urinary deposits.

Hippuric Acid was first detected in horses' urine by Liebig, and was proved by him to exist in healthy human urine in small quantity—a statement which has been confirmed by Lehmann, and recently by Kühne and Hallwachs. It is not found in the urine of carnivorous animals, but among herbivora it occurs in considerable quantity. It does not exist in large quantity in the urine of calves while sucking, but cows' urine contains as much as 1·3 per cent. Lehmann has detected it in considerable quantity in the urine of the tortoise (*testudo græca*).

Hippuric acid is soluble in about six hundred times its weight of cold water. It is very soluble in hot water, and also in alcohol; but is insoluble in ether. It crystallises very readily in various forms, which are derived from the right rhombic prism. (*Illustrations of Urine*, Plate IX, Fig. 1.) It is very easily decomposed into benzoic acid, especially in the presence of extractive matters, and other constituents of the urine. In testing for this substance, the perfectly fresh urine only should be employed. It is curious that benzoic acid, when taken into the organism, is eliminated in the urine in the form of hippuric acid—a fact which was first made known by Mr. Ure.

It may be prepared by adding milk of lime to fresh cows' urine. The mixture is to be boiled for a few minutes, strained, and exactly neutralised with hydrochloric acid. The solution is next to be boiled down to one-eighth of its original bulk, and considerable excess of hydrochloric acid added, when brown crystals of the acid form. These may be purified by solution in water, through which a current of chlorine is to be transmitted, in order to decolorise the liquid. It may always be readily obtained from human urine after taking ten grains of benzoic acid.

The quantity of hippuric acid is increased when a purely vegetable diet is taken; but it is certain that the whole of the hippuric acid formed in the organism is not derived from this

source. The proportion of hippuric acid in human urine was formerly considered to be so small that it was scarcely possible to make a satisfactory quantitative determination; but Hallwachs has lately shown that as much as *thirty grains* or upwards are excreted in twenty-four hours.

Very little is known with reference to the formation of hippuric acid; and, although the subject has been very carefully investigated by Kühne and Hallwachs, who have published two very elaborate memoirs, there still remains much to be discovered. These observers hold that the hippuric acid is produced from the glycocol formed in the liver. Hallwachs is led to conclude, from numerous experiments, that the production of hippuric acid is determined rather by the chemical changes going on in the organism, than by any peculiarities of the food; for, if a purely animal diet was taken, hippuric acid was still found in the urine.* Lehmann found much hippuric acid in the urine of fever patients, and always detected it in diabetic urine.

Robin and Verdeil give drawings of some crystals which they found in the urine of a man aged 30, who took little exercise, but lived on a highly nitrogenised diet; and which they considered to be hippuric acid: a statement apparently founded upon the resemblance of these crystals to those produced by the decomposition of hippurate of soda. They do not mention that the crystals were subjected to any chemical examination; and, in the absence of stronger evidence than mere resemblance in form, it seems to me that we are hardly justified in assuming that the crystals were composed of hippuric acid. It is very doubtful if this acid ever crystallises in urine spontaneously.

Extractive Matters. Under the head of extractive matters are included certain organic substances which have never been obtained in a state of perfect purity, which are uncrystallisable

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* An excellent review of these researches will be found in vol. xlv, p. 156, of the "Medico-Chirurgical Review".

—not volatile without decomposition—and incapable of being isolated. Chemists have described several kinds of extractive matters characterised by their behaviour with solutions of acetate of lead, bichloride of mercury, tincture of galls, etc. Within the last few years, however, several bodies, formerly included under the indefinite term of extractive matters, have been separated, and their chemical properties accurately determined. As instances, I need only mention albuminate of soda, binoxide and teroxide of protein, creatin and creatinine, hippuric acid, lactic acid and lactates, and certain colouring matters. The extractive matters in urine are entirely excrementitious; but it seems most probable that those present in the blood represent a certain stage of the metamorphosis of some of the constituents of that fluid—either a state intermediate between the nutritive pabulum and the tissue into which it is to be converted (progressive metamorphosis or histogenesis), or a condition resulting from the disintegration of tissue previous to its elimination from the body in the form of urea, creatine, uric acid, etc. (regressive metamorphosis or histolysis). The extractive matters of urine may be divided into three kinds.

Water Extract. The first is called water extract, because it is insoluble in absolute alcohol, and in spirit of specific gravity ·833, but is soluble in water. It exists only in small quantity. Infusion of galls and bichloride of mercury produce scarcely any effect upon it, but neutral and basic acetates of lead give copious precipitates.

Spirit Extract. The second kind of extractive matter is termed spirit extract, because it is insoluble in absolute alcohol, but soluble in water, and in spirit ·833. It contains much chloride of sodium. The solution of this extract is unaffected by infusion of galls, bichloride of mercury, and neutral acetate of lead; but a bulky precipitate is caused by basic acetate of lead.

Alcohol Extract. The alcohol extract is soluble in water, in

spirit ·833, and also in absolute alcohol. Its chemical reaction appears to be very similar to the last.

These are the extractive matters which are met with in healthy urine. In certain diseases, however, extractives drain off from the blood, and sometimes in very large quantity, which are not present in a state of health. My friend Dr. G. O. Rees many years since showed that this extractive could be detected in morbid urine by adding tincture of galls; and that the proportion varied greatly in different cases. Healthy urine is scarcely affected by tincture of galls, but this blood-extractive is at once precipitated by it. In order to detect it, tincture of galls is to be added to the filtered fluid; and, if this extractive is present, a precipitate is *at once* produced. Should the urine contain albumen, this must, in the first instance, be separated by boiling and filtration. It is only the precipitate which *immediately* follows the addition of the tincture of galls that must be noticed. In some cases, the extractive drains away from the blood, without the escape of albumen. (Lettsomian Lectures, by G. O. Rees, M.D., F.R.S.; *Medical Gazette*, 1851.) I shall have occasion to recur again to this interesting subject, when discussing the characters of the urine in disease.

One thousand grains of healthy urine will contain from fifteen to twenty grains of extractive matters. The solid matter contains from 15 to 40 per cent. of these substances.

The physiological importance of extractive matters is quite unknown, and hitherto no one has been able to ascertain their nature or discover the part which they play in the animal economy. Their presence in the blood, and in all the animal fluids, as well as in the solid organs and in the excretions, clearly prove them to be substances of great importance; and it must be remembered that, in the urine, the proportion of extractive matter is often greater than that of the urea itself. The amount of extractive matters in the different fluids and

secretions of the body is a subject well worthy of investigation, and likely to yield valuable results.

Vesical Mucus. Vesical mucus exists in very small quantity in healthy urine. It forms a faint flocculent cloud, which settles towards the lower part of the fluid, after the specimen has been allowed to stand for some time. Under the microscope, it is seen to consist of granules, with a little epithelial *débris*, nuclei, and a few imperfectly formed epithelial cells. I shall have to allude to the nature of the so-called mucus-corpuscle when speaking of pus.

Lactic Acid. Lactic acid is not constantly present in healthy urine in quantities sufficient to be recognised; but sometimes it is found in the urine of persons who may be considered to be in tolerably good health. Liebig denied its existence in healthy urine altogether; but its presence in this fluid—at least, under certain physiological conditions, as stated many years ago by Berzelius—has been confirmed by Franz Simon, Lehmann, and others: although, on the other hand, it appears nearly certain that the salt assumed to be lactate of zinc by many observers was not really of this nature, but probably consisted of a combination of another acid, which, unlike lactic acid, contains nitrogen.

In order to ascertain the presence of lactic acid, a baryta salt should be first prepared, as Lehmann has recommended, from which a lime salt is easily formed by the addition of sulphate of lime. The lactate of lime crystallises in double brushes, as seen by the microscope. From the lime salt a copper salt is prepared by the addition of sulphate of copper. (*The Microscope, in its Application to Clinical Medicine*, 2nd edit., Figs. 123, 124, p. 123.) This is examined by the microscope. The lactate of copper is decomposed by placing a small bar of zinc in the solution; and upon this, in a short time, crystals of lactate of zinc are deposited, whose angles may be measured in the microscope. (*The Microscope*, etc., 2nd edit., Fig. 125, page 123.) For the details of this process, I must refer to

Lehmann's *Physiological Chemistry*, translated by Day, vol. i, page 91.

According to some observers, the phosphate of lime and the ammoniaco-magnesian phosphate are held in solution by the lactic acid. They may also be dissolved by the chloride of ammonium, according to Dr. G. O. Rees. MM. Cass and Henry have endeavoured to prove that the lactic acid exists in the form of lactate of urea. Lactates of soda and ammonia are also most probably present in the majority of cases. Lactic acid is occasionally met with in urine; and I have already referred to some other organic acids which are sometimes found.

Before we discuss the characters of the saline constituents of healthy urine, it is desirable to consider how a specimen of urine may be systematically examined.

Systematic Qualitative or Quantitative Analysis of Healthy Urine: Organic Constituents.

1. In the first place, the reaction and specific gravity of the specimen are to be taken, and any general points noticed. (Lecture I.)

2. Two portions of urine (500 or 1,000 grains) are to be placed in separate porcelain capsules, and evaporated to dryness with the cautions previously given. In the first portion, A, the *organic constituents* are to be estimated; in the second, B, the proportion of *salts* is to be ascertained.* A, when dry, is to be weighed; and thus the quantity of *water* is obtained. The residue is known to be quite dry when *two successive* weighings exactly correspond. The solid matter is to be treated with successive portions of boiling alcohol, until nothing more is taken up. These are decanted into another basin, or passed through a filter; and the alcoholic solution, containing urea

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* B will be examined in Lecture III.

and extractives, is to be evaporated nearly to dryness—alcohol extract—C; the residue insoluble in alcohol—D.

C. The alcohol extract is to be treated with a few drops of water, and placed over the water-bath. Crystals of oxalic acid are to be added until they are no longer dissolved. It is important to add *excess* of oxalic acid crystals. The mixture is allowed to cool, and the impure crystals of oxalate of urea and excess of oxalic acid are to be slightly washed with ice-cold water, and pressed between folds of bibulous paper, to absorb the extractive matters. The crystals are to be redissolved in a small quantity of water, placed in a large vessel, and carbonate of lime added until effervescence has entirely ceased. After the mixture has been allowed to stand for some time, it is to be thrown upon a filter.

The solution separated from the oxalate of lime consists of *urea*, with a little colouring matter. It is to be carefully evaporated to dryness, and weighed. If the residue is not entirely soluble in alcohol, it contains impurity which must be deducted from the weight of the urea.

Or, the alcohol extract, C, may be treated with a few drops of water, so as to form a thick syrup; and nitric acid added by drops, while the basin which contains the extract is plunged in a freezing mixture. When sufficient nitric acid has been added to combine with all the urea present, the whole is to be allowed to stand for some time; the crystals carefully washed with a very little ice-cold water, and carefully placed on a porous tile, which will absorb the excess of nitric acid and the extractive matters, leaving crystals of *nitrate of urea*, which are to be carefully dried and weighed. By a simple calculation, the quantity of urea is easily ascertained.

D. The residue insoluble in alcohol is to be treated with boiling water, and thrown upon a filter. There remain upon the filter, *mucus* from the bladder and other parts of the urinary mucous membrane; *uric acid; phosphate of lime;* and *ammoniaco-magnesian phosphate*, with a mere trace of *silica*.

This residue is to be carefully dried and weighed. It is then to be incinerated; and, after the ash has been completely decarbonised, its weight is to be deducted from that of the residue insoluble in alcohol; and thus the proportion of uric acid and vesical mucus is ascertained. By deducting the united weight of all these different substances—urea, uric acid, mucus, and earthy phosphate—from the solid matter, we calculate the quantity of extractive matter present. According to this plan, we have ascertained the proportion of the following constituents in 500 or 1,000 grains of urine.

Water ....
Solid matter..........................
Urea ....
Extractive matters ....
Mucus and uric acid ....
Earthy phosphate and silica ....
Fixed salts ....

Many of the processes above described are imperfect, and likely to give results which are not quite accurate; still the plan is one which is practically useful, and, when a series of results is required, answers very well. In the analysis of animal fluids, it is impossible to attain to perfect accuracy, owing to the changes taking place in the ingredients of the fluid, which are produced by the analytical processes to which they are subjected. Moreover, in such inquiries, it is far more desirable to know the general change which takes place, under various circumstances, in the quantities of the different constituents, than to be acquainted with the exact absolute proportion of each present. In a future lecture, I shall allude to the *volumetric analysis* of healthy urine, which can be more quickly performed, but, at the same time, does not yield perfectly accurate results. (See also *Archives of Medicine*, No. I, p. 34.)

LECTURE III.

Healthy Urine. III. INORGANIC CONSTITUENTS. *On the Salts generally; Changes effected in the Composition of the Salts by Incineration: Proportion of the Saline Matter in Urine: Phosphates; Common Phosphate of Soda; Alkaline Phosphate of Soda; Acid Phosphate of Soda; Phosphate of Soda and Ammonia; Phosphate of Magnesia; Phosphate of Ammonia and Magnesia; Phosphate of Lime; Estimation of the Alkaline and Earthy Phosphates; Quantity: Sulphates; Quantity; Estimation: Carbonates: Chloride of Sodium; Quantity; Detection; Circumstances affecting the Excretion of Chloride of Sodium: Bases in Urine: Soda and Potash: Lime: Magnesia: Iron: Silica: Alumina: Systematic Quantitative and Qualitative Examination of the Saline Matter of Healthy Urine.*

III.—INORGANIC CONSTITUENTS OF HEALTHY URINE.

THE saline or inorganic constituents of healthy urine are composed of those substances which remain after the solid matter has been exposed to a red heat, and the carbon burnt off so as to leave a pure white ash. If a little of the solid matter be placed in a platinum capsule, or upon a piece of platinum foil, which should be very large in proportion to the quantity of solid matter operated on, and exposed to the red heat of a spirit or gas lamp, it will melt and boil, giving rise to the evolution of offensive gases, which result from the decomposition of the organic constituents of the urine. When this has ceased, a charred mass, consisting of carbon and the indestructible saline matters of the urine, remains. After this black spongy mass has been kept in the open capsule, at a dull

red heat, for a few hours, the carbon will gradually disappear, in consequence of the action of the oxygen of the air, which at this temperature combines with it, and forms carbonic acid. A pure white ash, which has an alkaline reaction, alone remains; and this consists entirely of saline or inorganic material, which is indestructible at a red heat.

Changes effected in the Composition of the Salts by Incineration. Now, it must not be concluded that the salts which we find in the ash existed in precisely the same state in the urine previous to incineration; for we know that many of these salts, when heated together, undergo mutual decomposition. Some of them may even be volatilised, if kept for a considerable time at a red heat. A mixture of carbonate of soda and chloride of ammonium becomes decomposed at a red heat. Chloride of sodium remains behind, while carbonate of ammonia is evolved. Any lactates, oxalates, and salts, of other organic acids present in the urine, will be found in the ash, in the form of carbonate, although no carbonate existed in the urine originally. The ammoniaco-magnesian or triple phosphate will be found in the ash as phosphate of magnesia; the phosphate of soda and ammonia, as phosphate of soda. Other phosphates also become completely changed by the process of incineration, and by the action of other salts present in the ash upon them. During the incineration, a considerable loss of chlorine also takes place.

Again, unoxidised substances, such as sulphur and phosphorus, and partially oxidised compounds, in combination with organic materials, will become oxidised in the process of decarbonisation; and will, therefore, be found in the ash in the form of sulphuric and phosphoric acid. These will react upon some of the bases present, and sulphates and phosphates will be formed.

Professor Rose of Berlin, in a beautiful series of experiments, has proved that the mineral constituents exist in very different states in various organic substances. From the *car*

bonaceous ash of some organic matters, the greater proportion of the salts can be extracted with water or acids; while, in other cases, but little saline matter can be separated, unless the mass be exposed to the oxidising action of the air for some time. This shows that the substances must have originally existed in an unoxidised or in a partially oxidised state, probably in combination with some organic material. In certain substances, then, the greater quantity of the mineral material is perfectly oxidised (*teleoxidic*); in others, it exists partly in an oxidised and partly in an unoxidised state (*meroxidic*). Professor Rose was not able to discover any substance in which it occurred completely unoxidised (*anoxidic*). In blood, milk, yolk of egg, and flesh, a considerable portion of the mineral constituents are *meroxidic;* while, in urine and bile, they are almost entirely *teleoxidic;* which is exactly what we should expect, when we consider the different nature and offices of these fluids.

Proportion of Saline Matter in Urine. About one-fourth of the solid matter of healthy urine consists of saline constituents which are not destroyed by a red heat.

One thousand grains of healthy urine, containing from forty to sixty grains of solid matter, will give from ten to fifteen grains of fixed salts. Of the salts, more than nine-tenths are soluble in water (alkaline salts); while the remainder can only be obtained in solution by adding an acid (earthy salts). A mere trace remains behind, which is insoluble in water, acids, and alkalies. This consists of silica, with perhaps a little carbon which has resisted oxidation. These numbers are, of course, only approximative, as the amount of salts is liable to great variation.

The saline constituents soluble in water are composed of the following acids and bases.

Sulphuric acid (and sulphur)	Potash (and potassium)
Phosphoric acid	Soda (and sodium).
Hydrochloric acid (chlorine)	

The salts may be readily obtained in a crystalline state by dissolving the residue in hot water, and evaporating a few drops of the solution on a glass slide. The crystals are represented in the *Illustrations of Urine*, Pl. I, Fig. 2.

The mineral constituents insoluble in water are composed of the following acids and bases.

Phosphoric acid	Lime
Carbonic acid (occasionally)	Magnesia
Silicic acid or silica	Alumina (sometimes).

In disease, the mineral constituents have been found to vary in quantity quite as much as the organic substances; and other salts are not unfrequently found, which will come under our notice at a future time: while occasionally one or more of the saline compounds mentioned in the above list are altogether absent.

The organic constituents of the urine have hitherto received a greater share of attention than has been given to the inorganic salts; but, from recent investigations, it seems probable that, before long, the physician will regard a departure from the healthy standard in the saline constituents, with as much attention as he has been accustomed to observe an increase or diminution in the quantity of the urea, uric acid, or other organic ingredients.

Phosphates. The phosphates are a very important class of salts, which exist in greater or less quantity in all the tissues of the body, in the secretions, and in considerable proportion in the blood. The salts of phosphoric acid which are carried off from the organism in the urine, may be divided into two classes.

1. The *alkaline phosphates* are *soluble* in water, and are not precipitated from their solutions by ammonia or other alkalies. When ammonia is added to healthy urine, the *alkaline* phosphates are not thrown down. Some of the most important alkaline phosphates are, *phosphate of soda, acid phosphate of soda*, and *phosphate of soda and ammonia.*

2. The earthy phosphates are *insoluble* in water, but are dissolved by the mineral acids. Most are soluble in organic acids, although they dissolve very slowly if the acids are dilute. They are held in solution even by carbonic acid. Most albuminous substances have the power of dissolving earthy phosphates; and casein holds in solution a considerable quantity of phosphate of lime. The earthy phosphates, as phosphate of lime and phosphate of magnesia, are always precipitated when ammonia is added to healthy urine.

Of the phosphoric acid eliminated in the urine in the form of phosphates, the greater proportion is doubtless taken in the food; but a certain amount is formed in the organism by the oxidation of the phosphorus of albuminous tissues, which takes place during their disintegration. Much of the phosphoric acid formed in the organism is doubtless produced in the nervous tissue.

In these lectures, I have purposely avoided the use of chemical formulæ, partly because, in many instances, I should have had to enter too far into the province of chemistry to explain them, and partly because I felt that all that was necessary for the clinical examination of the urine might be explained without their use. It is, however, impossible to allude to the composition of the phosphates without giving their chemical formulæ; and I therefore propose to make an exception in the case of this class of salts.

Phosphoric acid is one of those acids which exist in three forms—the monobasic, bibasic, and tribasic acids, which combine respectively with one, two, or three equivalents of base, to form three different classes of salts.

$$\text{Tribasic phosphates} \quad . \quad . \quad . \quad \left\{\begin{array}{l} 3\ NaO,\ PO^5+24\ Aq. \\ 2\ NaO,\ HO,\ PO^5+24\ Aq. \\ NaO,\ 2\ HO,\ PO^5,+2\ Aq. \\ NaO,\ HO,\ NH^4O,\ PO^5+8\ Aq. \end{array}\right.$$

Bibasic or pyrophosphates $2\ NaO,\ PO^5+10\ Aq.$

Monobasic or metaphosphates $NaO,\ PO^5.$

Now, the phosphates found in the organism are all *tribasic*

phosphates, and consist of three equivalents of base, combined with one equivalent of phosphoric acid, with different proportions of water of crystallisation. The elements of the base of a tribasic phosphate may be various. Thus, they may consist of three equivalents of soda or other base, or two equivalents of soda and one of water acting the part of a base, or one equivalent of soda and one of ammonia and one of water acting the part of a base, combined with one equivalent of phosphoric acid.

The chemical composition of the phosphates occurring in urine is represented in the following table.

Common or rhombic phosphate of soda, having an alkaline reaction	$2\,NaO, HO, PO^5 + 24\,Aq.$
Acid phosphate of soda, having an acid reaction . . .	$2\,HO, NaO, PO^5 + 2\,Aq.$
Alkaline phosphate of soda, having a highly alkaline reaction	$3\,NaO, PO^5, + 24\,Aq.$
Phosphate of potash* . .	$3\,KO, PO^5.$
Phosphate of ammonia and magnesia, ammoniaco-magnesian or triple phosphate .	$2\,MgO, NH^4O, PO^5 + 12\,Aq.$
Acid phosphate of lime . .	$2\,CaO, HO, PO^5 + 3\,Aq.$
Phosphate of lime (bone-phosphate)	$3\,CaO, PO^5$

Alkaline Phosphates.

Common Phosphate of Soda—$2\,NaO, HO, PO^5 + 24\,Aq.$ This salt exists in healthy urine in the proportion of about two grains in one thousand. The fixed salts contain perhaps from 20 to 30 per cent. of ordinary phosphate of soda. Its presence in healthy urine may be proved by adding absolute

* It is doubtful if phosphate of potash usually exists in urine, as chloride of sodium and phosphate of potash decompose each other, forming chloride of potassium and phosphate of soda. It is not improbable that it may exist in urine in which the chloride of sodium is present in very small quantity, or altogether absent, as in pneumonia and some other acute diseases.

alcohol to the syrupy fluid obtained by evaporating the urine over a water bath. This concentrated fluid is poured off from the salts which have crystallised, and placed in a small glass vessel. The alcohol is added; and, after the mixture has stood for some time, the crystals are deposited upon the sides of the glass. This method is given by Robin and Verdeil (*Traité de Chimie Anat. et Physiol.*, par Ch. Robin et F. Verdeil.)

Acid Phosphate of Soda—Na O, 2 HO, PO^5+12 Aq. This salt has only been found in the urine; and to it, at least in many cases, the acid reaction of the urine is due. This acid phosphate of soda may be formed from the common phosphate (which has an alkaline reaction), by the addition of uric acid, which removes from the common phosphate one equivalent of soda, forming *urate of soda*; and the reaction of the mixture becomes acid, in consequence of the formation of the *acid phosphate.*

The acid phosphate of soda may be obtained from the concentrated urine treated with absolute alcohol, after the separation of the common phosphate. The acid salt, which is much more soluble, becomes deposited in the course of a few days; but its separation may be expedited by the addition of ether. This phosphate has been separated from the urine by MM. Robin and Verdeil, who attribute the acid reaction of urine to its presence (*Comptes Rendus. Mém. de la Soc. de Biologie*, Paris, 1850, p. 25; also *Traité de Chimie Anat. et Physiol.*, 1853). The crystals of this salt are figured in Robin and Verdeil's *Atlas*, Pl. IX, Fig. 2.

Alkaline or Basic Phosphate of Soda—3 Na O, PO^5+24 Aq. This phosphate is considered by some to be present in urine; but it is so readily altered by other salts present, that it is impossible to obtain it from the animal fluids in a state of purity. In the presence of carbonic acid, it is decomposed: one equivalent of soda unites with the carbonic acid to form carbonate of soda, and common phosphate of soda is formed,

both which salts have an alkaline reaction—$3\ NaO, PO^5 + CO^2 + HO = 2\ NaO, HO, PO^5 + NaO, CO^2$.

Liebig has shown that it is not present in healthy urine, as was stated by Heller; and Messrs. Robin and Verdeil do not enumerate this phosphate as one of the constituents of urine: indeed, if this phosphate were formed, it would, in all probability, be at once resolved into salts of a more stable nature.

Phosphate of Soda and Ammonia—$NaO, NH^4O, HO, PO^5, +8\ Aq$. This salt, although probably not present in perfectly fresh urine, is usually enumerated as one of the phosphates found in the secretion. The crystals of phosphate of soda and ammonia, or microcosmic salt, are beautiful transparent four-sided prisms.

Phosphate of Potash—$3\ KO, PO^5$—is probably not present in healthy human urine; but it has been detected by Boussingault in the urine of the pig, in the proportion of 1·02 per 1000.

Many vegetable tissues contain a large quantity of phosphate of potash; and it is met with in the juice of muscle in considerable quantity.

The proportion of alkaline phosphates in the organism varies according to the nature of the food. Generally, the proportion is smaller in herbivorous than in carnivorous animals. Muscular fibre contains a large amount of phosphates. Wheat, and the seeds of the cerealia generally, contain a considerable quantity of alkaline phosphates. Robin and Verdeil found in the ash of the blood of a dog fed upon flesh as much as 12 per cent. of phosphoric acid, combined with soda and potash; while the ash of the blood of the ox did not contain more than 3 per cent. When the dog was fed upon potatoes, the proportion fell to 9 per cent. The ash of the blood of man contained about 10 per cent. of phosphoric acid. In urine, Berzelius found 2·94 per 1000; and Simon, from 1·25 in slightly acid urine, to 2·75 in very acid urine.

Breed and Winter estimate the quantity of phosphoric acid removed from the organism in the urine, in the course of

twenty-four hours, at from 59·48 to 79·97 grains. The proportion increased considerably after taking food. This quantity corresponds to from 120 to 160 grains of phosphatic salts.

The quantity of phosphoric acid increases for some hours after a meal. Vogel, Winter, and others, have made numerous experiments on this point; and their researches show that the hourly variation in the excretion of phosphate is regular. The morning urine contains the smallest quantity. In some of Dr. Bence Jones's analyses, however, the quantity of alkaline phosphates is even greater in the urine passed before than in that excreted after a meal (*Animal Chemistry*, p. 81).

The proportion of phosphates in the urine depends much upon the nature of the food. The quantity is increased if phosphorus be taken, proving that this substance does become oxidised in the organism. That the greater proportion of the alkaline phosphates present in the urine are derived from the food is rendered evident by referring to the amount introduced into the organism in this manner. A man taking about fourteen ounces of bread and twelve ounces of meat, with half a pound of potatoes and half a pint of milk, would take about 130 grains of alkaline phosphates.* As we have seen, he would eliminate, in his urine, about the same quantity. These numbers are only to be regarded as rough approximations to the truth; but I think, at present, it must be admitted that the quantity of phosphate excreted in the urine, and formed in the organism, is so small in comparison to that derived from the food, of which the amount is liable to great variation, that, in the present state of animal chemistry, it is quite impossible to form an estimate of the amount

* 14 oz. of bread	contain	53·2	grs. of phosphates.
12 oz. of beef	"	40·7	" "
½ lb. of potatoes	"	11·0	" "
½ pint of milk	"	32·0	" "
		136·9	grs. of mixed phosphates.

derived from the former source, or to separate this from the phosphates taken in the ingesta.

Still it is certain that some of the phosphoric acid is formed within the organism, by the oxidation of the phosphorus of the albuminous tissues; but this must bear but a small proportion to the whole amount of phosphate removed in the urine, as the above data conclusively show.

The fluid which surrounds the elementary fibres of muscle has an acid reaction, depending probably upon the presence of acid phosphate of soda, produced by the action of lactic or some other organic acid upon phosphate of soda. Du Bois Raymond has, however, shown that this acid reaction is not met with when the muscles are at rest. The ashes of most tissues contain phosphates in large proportion; and Schmidt has shown that a considerable quantity of phosphate is always present in young tissues. The quantity of alkaline phosphate required by the organism is considerable; for, besides the large proportion which is excreted in the urine, the ash of the solid excrements contains as much as 20 per cent. alone. The phosphoric acid required is, no doubt, supplied principally by the food, partly in the form of phosphatic salts, partly as phosphorus which is oxidised in the organism. We shall recur to this subject when we have to consider the elimination of the phosphates in disease.

Earthy Phosphates.

The earthy phosphates met with in the urine are—1. The *ammoniaco-magnesian phosphate*, also termed *triple phosphate*, or *phosphate of ammonia and magnesia*; 2. *Basic phosphate of ammonia and magnesia*; 3. *Phosphate of Magnesia.*

These earthy phosphates occur in very small quantity in urine. The secretion in health contains not more than from 1 to 1·5 part in 1000, and the solid matter contains from 1·5 to 2 per cent. The quantity present in different cases undergoes but slight variation, and seems to be determined, to a

great extent, independently of the chemical changes going on in the body. Most of the solids and fluids of the organism contain small quantities of the earthy phosphates. The amount depends in great measure upon the quantity of alkaline earths present.

In healthy urine, these earthy phosphates are held in solution, in all probability, by the free acid of the urine, and in some measure by the acid phosphate of soda. The chloride of ammonium present may also contribute to maintain the earthy phosphates in solution in the urine (Dr. G. O. Rees). Very slight changes are sufficient to cause the precipitation of the ammoniaco-magnesian phosphate; and beautiful crystals of this salt are sometimes formed in urine which has a decidedly acid reaction.

We must carefully distinguish between *excess* of phosphates in the urine and a *deposit* of earthy phosphate; for we may suppose a large quantity of earthy phosphate in urine to pass unnoticed by the practitioner, because it is in a state of *solution;* while a smaller quantity in an *insoluble* state is likely to receive from him a larger share of attention than its slight importance demands.

Precipitation of Earthy Phosphates by Heat. It is very important to bear in mind that the earthy phosphates are precipitated from some specimens of urine by heat. This precipitate closely resembles that which is produced, in many specimens of albuminous urine, upon the application of heat. It is, however, at once distinguished from albumen by the addition of a few drops of nitric acid, which instantly dissolves the phosphate, while albumen is unaffected by it. Such a mistake has many times been made; and I need hardly say how important it is to avoid the possibility of such an error, as it may lead the practitioner to form an unfavourable prognosis in a case in which there is really no cause whatever for anxiety. The cause of this occasional precipitation of earthy phosphate is obscure. By Dr. Rees it is attributed to an excess of the

phosphates being held in solution by chloride of ammonium. Dr. Brett considers that in these cases it is dissolved by carbonic acid; while Dr. Bence Jones attributes this precipitation to the excess of free acid of the urine being neutralised by an alkali, or by common phosphate of soda.

Phosphate of Lime—3 Ca O, PO^5—exists in healthy urine dissolved in acids, in certain salts, or in organic matters. Phosphate of lime is soluble in a solution of carbonic acid, in bicarbonates, and in chloride of ammonium. Albumen and fibrine always retain a certain quantity, and casein holds a large amount in solution. It is found in almost all the tissues, and, when separated, usually occurs in an amorphous state. The ash of urine contains between 2 and 3 per cent. of this phosphate, and that of excrements upwards of 12 per cent. It may be obtained in quantity from bones.

Acid Phosphate of Lime—2 Ca O, HO, PO^5+3 HO. The existence of this phosphate in urine constantly, is questionable; but, as before remarked, the composition of the phosphates is constantly altering; and an acid phosphate of lime is readily formed by the action of an organic acid on the neutral phosphate of lime.

Phosphate of Ammonia and Magnesia, Triple, or Ammoniaco-Magnesian, Phosphate—NH^4 O, 2 Mg O, PO^5+12 HO. The presence of this salt, which is so frequently met with in the animal fluids, usually depends upon decomposition having commenced, in which case the ammonia set free combines with the phosphate of magnesia to form the triple phosphate. At the same time, there can be no doubt that crystals of triple phosphate are sometimes found in acid urine—not merely forming a pellicle which alone is alkaline, while the fluid beneath retains its acidity (Thudichum)—but as a distinct deposit, leaving a clear supernatant fluid. Lehmann and other observers doubt the correctness of this observation; but the fact has been observed in this country several times, and I have noticed it myself more than once or twice. It is quite

possible that the acid reaction may depend upon chloride of ammonium, or some other neutral salt which reddens litmus, and not upon the existence of a free acid.

Crystals of triple phosphate are slightly soluble in pure water, but are rendered quite insoluble by a trace of ammonia and ammoniacal salts. They give beautiful colours when examined with a ray of polarised light.

Phosphate of Magnesia—$3\ MgO, PO^5+7\ Aq$. This phosphate is found in considerable quantity in the urine of certain herbivorous animals, and it appears to be a constituent of certain urinary calculi. It is doubtful if it is often present in human urine; but Robin and Verdeil have discovered it in several organs, and also in morbid products. In animal fluids generally, the phosphate of magnesia combines with ammonia, forming the salt which has just been described. When discussing the deposits of phosphates, I shall have to revert to this subject.

Microscopical Characters of the Earthy Phosphates. The phosphate of lime is usually deposited from urine in an amorphous form. Under the microscope, even when the highest powers are employed, the deposit is found to consist of minute granules. (*Illustrations*, Plate XXI, fig. 4.) Occasionally it occurs as round or oval particles of a high refractive power. Sometimes two of these small particles are connected together, and produce a crystal of the dumb-bell form. They vary much in size, but are usually very small.

The phosphates of magnesia crystallise in several different forms, which seem to be determined by slight changes in circumstances. The first is the stellate form, which occurs when ammonia is added to healthy human urine. The crystal consists of from four to five feathery rays, with a minute oval mass situated at the origin of each ray from the centre. These crystals gradually assume the more common form of the triple phosphate: secondly, that of a beautiful triangular prism, with obliquely truncated extremities. Great variation, however, is observed

in the form of these crystals; sometimes they appear almost square; and frequently they might be mistaken for octohedra, in consequence of the approximation of the obliquely truncated ends, and the shortening of the intermediate portion of the crystal. The feathery crystals of triple phosphate are represented in the *Illustrations*, Plate IX, fig. 2. After standing for some time, the rays alter in shape, and gradually little triangular crystals begin to make their appearance, as represented at *a*. After the lapse of some days, they are entirely converted into the ordinary triangular crystals. (Pl. IX, fig. 1; Pl. XXI, figs. 1, 3; Pl. XXIII, fig. 1.) An unusual form of magnesian phosphate crystals is represented in fig. 237, p. 324, of *The Microscope in its Application to Practical Medicine.*

Estimation of the Earthy and Alkaline Phosphates. The earthy phosphates (*phosphate of lime* and *phosphate of magnesia)* are easily detected by ammonia. If I add a few drops of solution of ammonia to this specimen of healthy urine, a turbidity is soon observed, owing to the precipitation of phosphate of lime in an amorphous form, and triple or ammoniaco-magnesian phosphate in flocculent snow-like crystals, which increase in size for some time after their first precipitation. Stirring favours the separation of the phosphates; but the form of the crystals must, of course, be studied in a mixture which has been allowed to remain quiet. If it is required to estimate the proportion of these earthy phosphates, it is only necessary to separate them by filtration, ignite in a platinum capsule, and weigh the ash.

Alkaline Phosphates. The phosphoric acid combined with the alkalies may be precipitated from the fluid filtered from the earthy phosphates by the addition of a salt of lime or magnesia, when an insoluble deposit, composed of phosphate of lime or phosphate of ammonia and magnesia, is produced. If we wish to ascertain the quantity of alkaline phosphates present, it is only necessary to filter the precipitate, dry, ignite, and weigh it. From the phosphate of lime or phosphate of

magnesia it is easy to calculate the proportion of phosphoric acid present; but, for ordinary purposes, it is enough to consider the weight as corresponding to the quantity of alkaline phosphates present in the urine, there being but slight difference in the equivalent numbers of the salts. The volumetric method of estimation, in which the phosphate is precipitated by a persalt of iron, will be described in a future lecture. Nitrate of silver produces in urine a yellow precipitate of tribasic phosphate of silver, which is soluble both in excess of ammonia and also in nitric acid. Upon adding a few drops of the former to the yellow deposit in this test-tube, it instantly dissolves. Now, when I add just nitric acid enough to neutralise the ammonia present, the yellow precipitate reappears; but, when I allow one drop more to fall in, it is immediately redissolved. I might repeat this many times. The precipitate of *chloride* of silver is quite *insoluble* in nitric acid, although soluble in ammonia; so that, in testing for chloride of sodium in urine, it is always important to add a few drops of nitric acid, to prevent the precipitation of the phosphate of silver.

Sulphates. Unlike the phosphates, the sulphates are present in very small quantities in the fluids of the body generally. The urine, however, contains a large quantity. This class of salts is not present in the milk, bile, or gastric juice. The blood contains only ·20 per 1000; while, in healthy urine, sulphates exist in the proportion of from 3 to 7 parts per 1000.

The proportion of sulphates undergoes a considerable increase after violent exercise, and under the influence of a purely animal diet—conditions under which the urea suffers a considerable augmentation. In fact, in all those conditions which are associated with an increased formation of urea, a large proportion of sulphates will also be observed. It would appear that the oxygen, hydrogen, carbon, and nitrogen of the albuminous substances, are eliminated in the form of urea; while the sulphur is removed in the state of sulphuric acid.

Dr. Bence Jones's experiments have shown that both vege-

table and animal food increase the proportion of sulphates in the urine. When sulphuric acid, sulphur, or sulphates, are taken internally, the amount of these salts is augmented. These facts prove that the sulphates found in the urine are in great part formed during the disintegration of tissues. They must be regarded as excrementitious, and are probably not concerned in nutrition.

The sulphuric acid eliminated in the urine occurs in the form of sulphate of potash and soda.

The urine contains about 3·5 grains per 1000 of sulphate of potash, and about 3·0 grains of sulphate of soda. About thirty grains of sulphuric acid, corresponding to about fifty-seven grains of the mixed sulphates, are excreted by a healthy man in twenty-four hours.

Sulphate of Lime has not been detected in human urine, but it has been found in that of animals, and is a constituent of some urinary calculi. I have seen crystals of sulphate of lime in the uriniferous tubes; and it is probable that it may be present in the urine, in some cases, in appreciable quantity. Traces of sulphate of lime are found in the blood. It is found in the pancreatic juice which has been kept for a few hours in a warm place, so that decomposition of some of the organic materials may take place.

The sulphates present in the urine are all soluble, like the alkaline phosphates; and, in order to prove their presence in a fluid, it is necessary to add some salt, the base of which forms an insoluble precipitate with sulphuric acid. Baryta salts are the most convenient for this purpose. Either the nitrate of baryta or the chloride of barium may be employed. In testing for sulphates in urine, it is necessary to add a little free nitric or hydrochloric acid previous to the addition of the baryta salt, in order to prevent the precipitation of a *phosphate* as well as a *sulphate* of baryta. The former is very soluble in free acid; the latter quite insoluble. If the quantity of sulphate is to be estimated, it is necessary to boil the mixture, or to drop the

baryta salt into the boiling solution; otherwise the precipitated sulphate of baryta will pass through the pores of the filter. The phosphoric acid may be estimated in the clear fluid which passes through the filter by the addition of ammonia, which throws down phosphate of baryta. The contact of the air must, in this case, be avoided.

Carbonates. Carbonate of soda is not usually reckoned as a constituent of healthy urine, as its presence is entirely dependent upon the kind of food which the person has taken. For instance, carbonate of soda will often be found in the urine after large quantities of fruit have been eaten, in consequence of the salts of the vegetable acids becoming converted into carbonates during their passage through the organism. In the urine of herbivorous animals, alkaline carbonates are found; and frequently the carbonate of lime is also present. In the urine of rodents, these salts, particularly the latter, are abundant. Moreover, carbonate of soda may actually have been present in the urine, although it cannot be detected in the ash; for, if common phosphate of soda be heated with carbonate of soda, the carbonic acid is expelled, and the tribasic phosphate of soda remains. Hence the absence of carbonate from the ash of urine is not always a positive proof that the fluid did not contain lactates before it was subjected to chemical operations. On the other hand, a carbonate may be detected in the ash, although none was present in the urine, in consequence of the decomposition of oxalates and lactates during incineration.

Testing for Carbonate. The presence of carbonic acid is very easily recognised by the effervescence set up immediately a little dilute acid is added to the ash. The best plan to test for carbonate in the ash is the following. A small portion of the dry ash is placed on a glass slide, and covered lightly with an ordinary square of thin glass. A drop of acid is then allowed to fall on the glass, so that it will gradually pass between the glasses by capillary attraction, and come into contact with the salt. If

any bubbles of gas escape in consequence of the action of the acid, they will be confined beneath the thin glass, and one cannot fail to see them. If they be very small, the specimens may be subjected to microscopical examination. In this manner, the slightest trace of carbonic acid can hardly escape notice.

If the quantity of carbonate is to be estimated, the ash must be placed in a little apparatus, from which the gas is conducted by a tube into another vessel containing lime or baryta water; or it may be caused to pass through the potash apparatus used in organic analysis. From the weight of the carbonate, that of the carbonic acid is easily calculated. In the last case, its weight is obtained directly.

Chloride of Sodium. Common salt is always present in healthy urine, although the proportion is liable to great variation, owing to the circumstance that the chloride of sodium is always derived from the food. The importance of this substance to the organism is sufficiently proved by the fact that all kinds of food contain a certain quantity, and almost every specimen of water holds some proportion in solution. Again, it is well known that the health of animals deprived of the proper amount of salt deteriorates. It is to be detected in nearly all the tissues of the animal body, and is found in large quantity wherever cell-development is actively going on. This is true both with regard to healthy tissues and morbid growths. Common salt crystallises in cubes; but, in the presence of urea and some other organic substances, it assumes the form of a regular octohedron. As is well known, it is readily soluble in water (31·84 parts in 100), diffuses itself rapidly through a large bulk of fluid, and, in a dilute state, permeates tissues with great facility.

Besides common salt, urine also contains a certain quantity of chloride of potassium.

Quantity. Healthy urine contains from three to eight grains of chloride of sodium in 1000; the solid matter, about 6 per

cent.; and the fixed salts, about 25 per cent. or more. Under ordinary circumstances, from 100 to 300 grains of salt are removed from the body in twenty-four hours; but the proportion is influenced by a great variety of circumstances, and is especially affected by the quantity of fluids taken. The amount is very variable in different individuals, according to the proportion of salt taken with the food. The secretion of chloride of sodium, as you would suppose, attains its maximum a few hours after a meal, and but little is eliminated during the night.

Detection. Chloride of sodium is very easily detected in urine. It is only necessary to acidulate the specimen with a few drops of nitric acid, and then add nitrate of silver. The white precipitate of chloride of silver is quite insoluble in nitric acid, but soluble in ammonia. In order to make a quantitative determination, the chloride of silver is to be dried; and it should be burnt and fused in a *porcelain* capsule before being weighed. The volumetric process, however, is the most accurate.

Circumstances affecting the Excretion of Salt. Chloride of sodium is not formed in the organism, but seems to exert some important and beneficial effects during its passage through the tissues; and whenever the nutritive changes are very active, there seems to be an unusual demand for chloride of sodium. But the precise part which the substance plays is at present unknown. The quantity of salt excreted in the urine undergoes great changes in certain diseases. We shall consider them in a future lecture. The proportion also varies considerably from day to day, under the influence of an ordinary diet in health; and the ingestion of large quantities of water causes the elimination of a greatly increased amount of common salt. Thus, in one experiment, continued for four days, the following results were obtained: During the first three days, about thirty-six ounces of urine were passed per diem; the specific gravity aried from 1015 to 1024. The total quantity of solid matter

passed in twenty-four hours was about 750 grains, and the chloride of sodium amounted to 113 grains. On the fourth day a large quantity of water was taken; 258½ ounces of urine, of specific gravity 1003, were passed; containing a total of 1034·48 grains of solids, and 232·8 grains of chloride of sodium. The phosphoric acid was diminished, and the sulphuric acid was increased by upwards of one-third.*

Soda and Potash. In healthy urine but a very small quantity of potassium is present in the form of chloride; but of soda salts there is a large proportion. The potash salts, as was first pointed out by Liebig, are found in considerable quantities in the muscles, while the soda salts predominate in the blood. Although phosphate of potash be taken in the food, the corresponding soda salt, which is necessary to the blood, is still found in that fluid; and there can be no doubt that in the organism the chloride of sodium is decomposed by the phosphate of potash—a phosphate of soda, and a chloride of potassium being formed.

To separate the sodium from the potassium in urine, a somewhat tedious analysis, of which I will just give a rough outline, is necessary. After destroying the organic matter by ignition, the whole of the phosphoric and sulphuric acids are removed, and the potassium and sodium converted into chlorides. A solution of bichloride of platinum is then added, and a chloride of potassium and platinum, and a chloride of sodium and platinum are formed. The potassium salt is most insoluble, and separates in the form of small octohedra, which do not polarize light. These may be separated by filtration. The sodium salt remains in solution, and may be obtained in the form of crystalline needles by concentrating the solution. These crystals exhibit the most beautiful colours when a ray of polarized light is transmitted through them.

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* These analyses were performed by my friend and former assistant, Dr. Von Bose.

Lime may be detected in urine by dissolving the salts in acetic acid, and adding a little oxalate of ammonia to the filtered solution. Oxalate of lime is precipitated as a white, granular powder, which passes through the pores of a filter, unless the mixture be boiled previous to filtration. As already mentioned, lime occurs in urine as a phosphate, and occasionally as a carbonate. It forms a urinary calculus very rarely met with in man; but not uncommon in some herbivorous animals. The urine of the horse always contains a number of spherical masses, composed of carbonate of lime, which may be regarded as microscopic calculi.

Magnesia must be precipitated as ammoniaco-magnesian phosphate, from a concentrated solution of the salts after the separation of the lime. The fluid should be evaporated to a small bulk, and when quite cold a little of the solution of phosphate of soda should be added to the mixture, rendered alkaline by the previous addition of ammonia; unless there be already a sufficient quantity of ammoniacal salt in the mixture, some muriate of ammonia should be added, as the magnesian salt is slightly soluble in pure water, but insoluble in solutions of ammoniacal salts.

The solution should be stirred in all cases, for by this means a precipitate can often be produced, although before not the slightest turbidity was observable.

Iron. Traces of iron may be detected in healthy urine if a large quantity of the secretion be operated upon. Like many other mineral substances, iron passes off in small quantities in the urine, and is generally found in the urine of persons taking preparations of iron. Dr. Harley has shown that iron is a constituent of one of the colouring matters of the urine (*Uræmatine*).

Silica. Berzelius, many years ago, demonstrated the presence of *silicic acid*, or silica, in urine. Mere traces are met with in the ash after the removal of the salts insoluble in water, by the addition of strong nitric acid. The silica remains undis-

solved. This substance is derived principally from wheat, which, like other plants belonging to the cerealia, contains a considerable proportion of silica. Silica has been occasionally met with in urinary calculi, in appreciable quantity.

Alumina. It has been stated by authorities that this substance does not pass off from the system in the urine at all; but from several observations which I made some years since, and which I have lately repeated, I have been led to conclude that it is very commonly present in the ash of urine. The alumina detected in the urine is in great part, if not entirely, derived from the alum taken in the bread. Some time since, while in the habit of eating pure home-made bread, I was unable to detect the presence of this substance in the manner presently to be described; but afterwards, when my diet consisted of baker's bread, I found very decided indications of its presence.

The test which has been employed is the ordinary blow-pipe test. A little of the fixed saline residue, which has been perfectly decarbonised, is moistened with a solution of nitrate of cobalt, and heated gradually in the blowpipe flame to a bright red heat. If alumina be present, the bead, upon cooling, is found to be of a beautiful *bright blue* colour. As is well known, there is great difficulty in separating phosphate of alumina from phosphate of lime; and the ordinary process of analysis is not sufficiently delicate to detect this substance in the small quantity in which it ordinarily occurs in the ash of urine. When the ash contains as much as one-fiftieth part, however, I have been able to detect it by the liquid tests. The blowpipe test above referred to is not without objection, inasmuch as any bead containing phosphates exhibits a blue colour when heated in the blowpipe with nitrate of cobalt. The blue colour produced is certainly very different to that developed when alumina is present. A bead consisting of phosphates of soda, lime, and magnesia, gave a very dull grayish blue colour with the cobalt; but, when the slightest trace of alumina was

added, a very bright and decided colour resulted. I have applied this test, therefore, to the urine salts before and after alum was taken in the food. In the first case, the blue tint was very undecided, or was not at all manifested; while in the last it was bright and distinct.

At a time when I was taking home-made bread perfectly free from alum, I examined the urine. The ash was tested for alumina with nitrate of cobalt in the usual manner, but only a faint blue colour was produced. Immediately after evacuating the bladder (12, noon), five grains of alum were taken, dissolved in an ounce and a half of distilled water. At 6 P.M., about fifteen ounces of urine were passed. A portion of this was evaporated to dryness, and the residue incinerated and decarbonised. A small quantity of the ash was treated with nitrate of cobalt, and heated in the blowpipe flame. The bead, on cooling, was of a very bright blue colour. This experiment was repeated, with the same result. A similar reaction is met with in a great many specimens of ash obtained from the urine of hospital patients. Although this is not a perfectly accurate test, it indicates the presence of alumina in some specimens of urine in which one would expect a salt of this base to be present; while in urine which was perfectly free from alumina, no indication of its presence was afforded by the test. I think, therefore, if the cobalt test be employed carefully, it is worthy of more trust than most chemists seem disposed to place in it. A further series of researches is required to prove the proportion of alumina removed in the urine to that which escapes by the intestinal canal, when salts of this base are taken with the food. But I think there can be little doubt that a certain amount of this substance is really carried off in the urine. The urine salts of most persons give a very decided reaction indicating the presence of this substance, a considerable quantity of which is taken with many kinds of bread. Although there are many objections to mixing alum with the bread, and the practice ought clearly to be put an end to, I am not aware that any

deleterious effects have been produced by its introduction. Some have attributed habitual constipation to this cause.

It is desirable that the student should be acquainted with the principal characters of the most important inorganic salts of urine; and it has been considered desirable to give the following short course of systematic analysis. When it is required to estimate the constituents quantitatively, the volumetric process will be found the most accurate as well as the most convenient.

Systematic Qualitative or Quantitative Analysis of Healthy Urine: Inorganic Constituents.

The portion of urine B (p. 39) is also to be evaporated to dryness, and the dry residue incinerated in a large platinum capsule, and maintained at a dull red heat until it is perfectly decarbonised and nothing remains but an almost perfectly white ash. This, consisting of the fixed salts, is now to be examined as follows. Boiling distilled water is to be poured upon the saline residue, and the mixture thrown upon a filter.

The *solution* contains the *alkaline salts.*

The *insoluble matter*, consisting of *phosphate of lime*, *phosphate of magnesia*, and *silica*, remains behind on the *filter*.

1. The residue *insoluble in water* is to be treated with nitric acid, and boiled if necessary. *Silica* remains undissolved. If effervescence occur upon the addition of the acid, *carbonate of lime* was present in the ash. Filter; add excess of ammonia to the filtered solution, and redissolve the precipitated phosphates by adding excess of acetic acid. Next precipitate the lime as oxalate, by the addition of oxalate of ammonia. If the *quantity* of lime is required, the oxalate must be heated in a platinum capsule, and weighed as carbonate.

After the separation of the oxalate of lime by filtration, concentrate the clear solution by evaporation, and add a little am-

monia and chloride of ammonium. Stir the mixture, and set it aside, that crystals of *triple or ammoniaco-magnesian phosphate* may form.

2. The *original solution*, containing the urinary salts, soluble in water, is divided into two portions, 2 *a*, 2 *b*.

2 *a*. The first portion acidified with nitric acid, and treated with *nitrate of silver*. *Chloride of silver*, indicating the presence of chlorine, is precipitated. The chlorine originally existed in combination principally with sodium.

2 *b*. The second portion is also to be acidified with nitric acid, and an excess of solution of nitrate of barytes added; a precipitate of *sulphate of barytes*, proving the presence of sulphuric acid, occurs.

The mixture is boiled and filtered; and, upon the addition of ammonia to the solution, *phosphate of baryta*, showing the presence of phosphoric acid, is precipitated, care being taken to prevent the formation of carbonate of baryta by exposure to the air.

Next the phosphate of baryta is to be separated by filtration; and the solution, which contains nitrate of barytes, ammonia, and the fixed alkalies, is to be concentrated. Excess of carbonate of ammonia and ammonia is to be added, and the mixture thrown upon a filter. The solution is to be concentrated by evaporation, and the barytes separated by sulphuric acid, after which the solution is to be evaporated to dryness, and the residue heated to redness in a hard glass tube, in the mouth of which a fragment of carbonate of ammonia has been placed. The residue is to be treated with water, and filtered. The solution contains the salts of the alkalies, *potash* and *soda*. The former is thrown down in the form of minute octohedral crystals of the *potassio-chloride of platinum*, upon the addition of a solution of bichloride of platinum. After stirring, these may be filtered off.

The solution contains the *sodio-chloride of platinum*. It is

to be concentrated, in order that the beautiful acicular crystals of this substance may form.

Thus we have shown the presence of the following substances in the specimen of urine submitted to examination.

Fixed Salts	....
Lime	....
Magnesia	....
Potash	....
Soda	....
Chlorine	....
Phosphoric Acid	....
Sulphuric Acid	....

The constituents not included in the above list, and in that on page 41, require special processes for their demonstration; and, as many of them exist in very minute quantity, it is not desirable that the student should attempt to test for them in the small amount of urine usually operated upon. If the observer desire to carry on special researches on these constituents, I must refer him to works which treat fully upon the processes of analysis, especially to Dr. Thudichum's recent work. The substances alluded to are the following:—

Creatine.	Ammonia.
Creatinine	Hippuric Acid.
Sarkine	Iron.
Uræmatine.	Alumina.*
Uroxanthine.	Carbonic Acid.
Phenylic Acid } ?	Leucine } †
Damaluric Acid } ?	Tyrosine } †

The characters of several of these have already been discussed, and the methods for separating them from the urine described.

Average Composition of Healthy Urine, and the Quantity of the different Constituents excreted in twenty-four Hours.

It is clearly very important that we should form a general idea of the quantitative composition of healthy urine, and the

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* Not necessarily present in healthy urine.

† In urine in certain diseases. Probably not in healthy urine.

amount of the various constituents which are excreted from the healthy organism in twenty-four hours. Those who are making observations on the urine in disease should be acquainted also with the relative proportion to each other of these different substances. It is true that the healthy variations are very great; but, in certain cases of disease, the difference in the quantity is so considerable that the observer cannot fail to be struck with the importance of the fact. Thus, in health, from 400 to 500 grains of urea are excreted in twenty-four hours. In certain cases of kidney-disease, when the cortical portion is impaired in structure, not more than 100 grains are eliminated; while, in some cases of fever, upwards of 1000 grains have been removed in the same time. Of the significance of such facts there can be no question; and the physician cannot fail to reflect upon the very different chemical conditions under which life is being carried on in these cases. Without considering all the circumstances likely to affect these abnormal processes, how can we hope ever to gain that insight into the nature of disease which in many instances can alone enable us to modify or counteract the morbid changes going on?

The composition of healthy urine is given in analyses by Berzelius, Lehmann, and Dr. Miller. With a view of giving a rough idea of the general amount of the different urinary constituents excreted, and the proportion which these bear to each other, in twenty-four hours, I propose to arrange the results of numerous observations in a tabular form. The proportion of some of these substances is so variable, that it is impossible to give an average. In most cases, I have purposely given a round number, and avoided fractional parts; but in other instances, in which I have not been able to institute examinations for myself, and when the question has only been examined by one or two observers, I have given the exact figures published by the authority who has made the matter an object of special study. In constructing this

table, I have not attempted to follow any single observer, but, with the exceptions alluded to, have put down numbers which appear to me to be tolerably correct. They have been obtained by consulting numerous authorities, and from my own analyses. This table, therefore, is only to be looked upon as a rough approximation to the truth. In the second column, the composition of 1000 grains of urine is given; in the third, the quantity of constituents in 100 grains of solid matter; and in the fourth, the percentage composition of the salts.

From what I have said before, it is obviously quite impossible to give what may be regarded as an *average* of the quantity of constituents removed in the urine in the course of twenty-four hours; since it will vary with the weight and power of the individual, the amount of exercise, quantity of food, etc. The figures in the table may be regarded as the proportion excreted by a strong healthy man in good nutrition, on full diet. Healthy women would excrete from one-third less to half the quantities given in the first column.

The same exception may be taken to the numbers expressing the *relative* amount of the different ingredients. For instance, the proportion of urea to extractive matters undergoes the greatest variation. Sometimes the urea is double the weight of the extractives, while in other cases the numbers would be reversed. Many of the saline constituents also exhibit the greatest variations, not only in different individuals, but in the same person, on different days. Thus the quantity of chlorides is twice as great on some days as on others; depending, as before remarked, partly on the amount taken in the food, partly upon the quantity of fluid and other saline matters. As yet, these extraordinary fluctuations have not fully been accounted for; but, doubtless, in time the circumstances which determine them will be accurately made out.

A. An analysis of 1,000 parts of healthy urine by Berzelius; B. One by C. G. Lehmann.

	A		B	
Water	933·00		932·019	
Solid matter . . .	67·00	100·0	67·981	100·0
Urea	30·10	44·9	32·909	48·4
Uric acid . . .	1·00	1·4	1·098	1.5
Lactic acid . .	17·14	25·5	1·513	2·3
Lactates . . .			1·732	2·6
Water extract . .			·632	1·0
Spirit & alcohol extract			10·872	16·0
Chloride of sodium . .	4·45	6·6	3·712	5·5
Chloride of ammonium .	1·50	2·2		
Alkaline sulphates . .	6·87	10·2	7·321	10·8
Phosphate of soda . .	2·94	4·3	3·989	5·9
Biphosphate of ammonia	1·65	2·4		
Phosphates of lime and magnesia . .	1·00	1·4	1·108	1·7
Mucus	·32	·4	·110	·3
Silica	·03	·04		

The following is an analysis of healthy urine by my friend Dr. W. A. Miller, of King's College:—

Specific gravity		1020	
Water		956·80	
Solid matter		43·2	100·00
Organic 29·79	Urea	14·23	33·00
	Uric acid . . .	·37	·86
	Alcohol extract . .	12·53	29·03
	Water extract . .	2·50	5·80
	Mucus	·16	·37
Fixed salts, 13·35	Chloride of sodium .	7·22	16·73
	Phosphoric acid . .	2·12	4·91
	Sulphuric acid . .	1·70	3·94
	Lime	·21	·49
	Magnesia . . .	·12	·28
	Potash	1·93	4·47
	Soda	·05	·12

Vogel gives the following estimate of the quantity of urine and its most important constituents excreted in twenty-four hours in a state of health:—

Average quantity in twenty-four hours	52¾ to 56 oz.
Average specific gravity	1·020
Average quantity of urea	556 grains.
Average quantity of chlorine . . .	154 „
Average quantity of free acid . . .	33 „
Average quantity of phosphoric acid .	66·7 „
Average quantity of sulphuric acid .	30·88„

Table showing the amount of Urinary Constituents excreted in twenty-four hours, and in 1000 parts of Healthy Urine, with the percentage composition of the Solid Matter and Fixed Salts.

	Excreted in twenty-four hours.	In one thousand parts of urine.	In one hundred grains of solid matter.	In one hundred grains of salts.
Specific gravity . . 1015 to 1025				
Quantity	40 oz. to 60 oz. 17500 grs. to 26250 grs.			
Water	16700—25050	968·0 —940·0		
Solid matter	800— 1200	32·0 — 60·0	100·0	
Organic matter . . .	600·0—900·0	24·0 — 45·0	75·0	
Saline matter . . .	200·0—300·0	8·0 — 15.0	25·0	100·00
Urea	400·0 —600·0	12·0 — 30·0	45·0	
Kreatine	3·45*— 6·32*			
Kreatinine	5·50*— 10·00*			
Uric acid	5·00— 8·00	·3 — 1·0	1·5	
Hippuric acid . . .	7·50*— 30·00†			
Extractives and colouring matter	140·0 —200·0	9·0 — 20·0	20·0	
Free acid	20·0 — 30·0	·32— ·64	1·0	
Ammoniacal salts . .	6·0 — 15·0	1·50— 3·00	5·0	
Mucus	10·0 — 30·0	·1 — ·4	1·0	
Sulphates	50·0 — 85·0	1·5 — 6·0	8·0	30·0
Alkaline phosphates . .	60·0 —100·0 or 160	2·0 — 9·0	9·0	38·0
Earthy phosphates . .	6·0 — 20·0	·5 — 1·2	1·5	6·0
Chlorides	100·0 —300·0	4·0 — 8·0 or more	7·0 or more	25·0 or more
Chlorine	60·0 —180·0	2·4 — 4·8	about 4·2	15·1
Sulphuric acid . . .	25·0 — 42·0	·75— 3·0	about 4·0	15·0
Phosphoric acid . .	30·0 — 50·0 or 80	1·0 — 4·5	about 4·5	19·0

The numbers in the first column are *high*, and must not be considered to represent the smallest proportions excreted consistent with health.

* Thudichum. † Hallwachs.

This table may perhaps assist you in some measure in remembering the general composition of healthy urine, and the proportion of the different constituents eliminated from the body in twenty-four hours. It is quite impossible to use this or any other table as a standard of reference, because the proportion of the urinary constituents secreted in health is very different in different individuals. Before we can judge if a man is passing too much or too little of any substance, we must ascertain his weight, and form some general idea of the activity of his vital actions when he is in a state of health. For instance, the statement that a patient is passing daily about 150 grains of urea indicates nothing; for a small woman in good health weighing 80 lbs., or even less, secretes daily even less than this; but if this amount only were excreted by a tall, strong, active, healthy man, weighing 170 lbs. or more, it would indicate a very serious condition, and we should at once know from this fact alone that he was in the greatest danger. The secreting structure of his kidneys must be temporarily or permanently affected, and, unless relief be afforded very soon, death must result from the accumulation of excrementitious substances in the blood.* Some observers calculate the quantity of solids of the urine, etc., which should be excreted for every pound of the individual's weight; but it is perhaps simpler to state the total weight of the person only, as just mentioned. If, therefore, you propose to conduct any series of researches upon the proportion of substances excreted in the urine, in health or disease, you must weigh the individual; and you must care-

* In many cases, the most valuable information bearing upon the progress of the case may be gained by the simple process of weighing the patient, which is too seldom adopted. All our hospitals and public institutions ought to be furnished with weighing machines. How often in the course of many diseases one desires to know simply if the patient has gained or lost in weight? The weighing machines which I have seen at present in use are very expensive, and not accurate. A good simple apparatus, which can be made for a moderate sum, is much required. I have just heard that Messrs. Weiss are constructing an improved apparatus suitable for the practitioner, but I believe the price of this will be ten guineas.

fully ascertain the amount of ingesta; and the quantity of excrementitious substances generally, including the sweat, if possible, must be estimated. Again, you will see how very little information you can gain from learning the composition of a given quantity of urine, without knowing the proportion excreted in the twenty-four hours. There is very much to be made out by carefully conducting series of researches of this kind in the cases of patients suffering from various acute affections; and, since the introduction of the volumetric process of analysis, which I shall describe in a future lecture, we have had great facilities for conducting such inquiries.

In the next lecture I propose to commence the consideration of the second part of my subject—*morbid urine.* It is not an easy task to define in few words exactly what is comprised in the term *morbid urine;* and I shall, therefore, not offer an exact definition, but merely draw a general distinction between *healthy urine,* in which the proper amount of all the constituents, relatively and absolutely, exists, and *morbid urine,* in which there is too much or too little of one or more of the substances occurring in health, or certain constituents are present which do not exist in the healthy secretion at all.

LECTURE IV.

URINE IN DISEASE. *Arrangement of the Subject. Diathesis.* EXCESS OR DEFICIENCY OF WATER AND THE ORGANIC CONSTITUENTS PRESENT IN HEALTH. *Excess of Water: Diabetes Insipidus: Deficiency of Water: Increased Acidity of Urine: Principles of Treatment: Nitric Acid in the Urine: Ammonia: on Detecting Urea in the Blood or Serum: on Detecting Ammonia in the Breath: Urea; Excess of Urea; Deficiency of Urea: Colouring Matter: Excess of Uric Acid and Urates: Principles of Treatment: Extractive Matters: General Remarks on the Increase of the Organic Constituents, with Analyses: Analyses of Urine in Chorea: Analyses of Urine in Skin-Disease.* EXCESS OR DEFICIENCY OF THE INORGANIC CONSTITUENTS PRESENT IN HEALTH. *Chloride of Sodium; its Diminution in Acute Inflammations: Sulphates; Increase in Cases of Chorea, Rheumatic Fever, etc.: Influence of Remedies: Alkaline Phosphates; Increased Secretion of Alkaline Phosphates in Inflammation of the Brain; Analyses; Earthy Phosphates; Increase in the Urine of Cases of Mollities Ossium; Analyses.*

URINE IN DISEASE.

BEFORE I describe in detail the particular characters in which a specimen of urine may differ from the secretion in its normal state, it is desirable to consider one or two questions of general interest, which can be more advantageously discussed here than in a future part of the course. It is also necessary that I should give you a sketch of the order in which the subject will be treated of.

Many alterations in urine, which have been termed "*morbid*",

really depend upon increased or diminished activity of the same chemical changes which occur in health. It is often very difficult to decide how far an alteration in the quantity or quality of the constituents should be attributed to physiological changes, or referred to morbid actions. We must also carefully bear in mind that important changes often occur after the urine has been passed, and may be due to the action of the air, fermentation caused by the presence of mucus, and a number of other circumstances. There are many alterations in the urine, depending upon a temporary derangement of those actions which occur in a state of health, which would not be properly described under the term healthy, but which, nevertheless, cannot properly be called morbid. I do not attempt, therefore, to divide *accurately*, healthy urine from morbid urine, and only wish you to look upon this as a sort of rough artificial division, adopted for convenience alone. Indeed, all such divisions are quite artificial; and no one attempts to assign accurate limits even to large and important branches of natural science, as anatomy, physiology, histology, botany, medicine, surgery, etc., which, merely for convenience, are treated of as separate subjects.

The functions of digestion, respiration, and circulation, are intimately concerned in the formation of those substances which are removed from the system in the urine. The characters of the secretion are much affected by the state of the skin and the action of the liver; and there are many other circumstances which may cause an alteration in the urine, independently of those numerous affections to which the urinary organs are exposed. Disease of the secreting structure of the kidney, or of any part of the complicated and extensive efferent channel by which the urine is carried off from the gland, may cause very important alterations in the characters of the secretion. Now, it is of great importance to us, as practitioners, to know that an examination of the urine materially assists us in endeavouring to ascertain the exact nature and

precise seat of the derangement. Sometimes we are able to diagnose the morbid alteration from an examination of the urine alone; but in almost all cases such an examination will afford important information bearing on the nature of the case. Certain substances, which are ordinarily eliminated in the urine, may, in consequence of morbid actions having been set up, be attracted to other parts of the body, or be eliminated through other channels. When the kidney itself is affected, the morbid condition may be temporary or permanent; and this can often be ascertained with certainty by examining the urine. The mucous membrane of the pelvis of the kidney, of the ureter, or of the bladder, may be the seat of the lesion, and thus the characters of the urine may be altered in a very important manner; or lastly, a certain effect may be produced by the growth of adjacent tumours, by causing pressure, altering the structure of the organs, etc.

The *ordinary constituents* may be in greater or less proportion than in health, or certain *soluble substances* not met with in the healthy secretion may find their way into the urine. As I have before remarked, a little mucus from the urinary passages is the only deposit which occurs in health. In disease, *insoluble deposits* are commonly met with. Substances which are comparatively, though perhaps not absolutely, insoluble (being soluble in a very large quantity of the secretion), may float upon the surface of the urine, or may be suspended throughout the fluid.

By *microscopical examination*, combined with chemical tests, we can make out the nature of a deposit. By *chemical analysis* alone, we can ascertain an abnormal proportion of substances present in health, or estimate the quantity of such as are not found in the healthy secretion.

Diathesis. Let me now ask your attention for a few minutes to the question of diathesis. The "uric acid", the "phosphatic", the "oxalic", the "sulphuric" *diatheses*, and others, are constantly spoken of. It is well that we should try to dis-

cover exactly what is understood by this term which is in such frequent use, and consider whether any real advantage is gained by employing it in the manner in which it is generally used. Although the word has been employed by very high authorities since the time of Dr. Prout, there appears to be some objection to its use as an explanation of the causes of the production of urinary deposits.

In the first place, with reference to the *uric acid diathesis;* this term has been applied to all cases in which the urine habitually contains deposits of uric acid and urates. This precipitation of uric acid in an insoluble form is due to a change taking place in the urine, at least in the majority of instances, *after* it has been secreted. Excess of uric acid may exist in the urine in two states, *dissolved in the fluid*, and in the form of an *insoluble deposit.* In the first case, the practitioner would not be cognisant of the excess; and a person may be passing a very considerable quantity of urates, in a state of solution, for a long time, without any notice being taken of the fact. On the other hand, a patient's urine may contain only the healthy proportion of uric acid; but this, owing to a change taking place after it has left the bladder, might be deposited in an insoluble form. From this circumstance alone, it would be inferred that the last patient had a disposition to the formation of a large quantity of uric acid (*uric acid diathesis*), while really there might be a much larger amount produced in the former instance.

Persons whose urine has deposited triple phosphate and phosphate of lime have been said to suffer from the phosphatic *diathesis;* while the deposition of the sediment depends, at least in the great majority of cases, upon a change effected in the urine after it has left the secreting part of the organ, and has not necessarily anything to do with the habit of body or peculiarity of constitution, or with the state of the blood.

Dr. Bence Jones defines the phosphatic diathesis and the sulphuric diathesis in the following terms:—" What I wish to

impress upon you now is, that the true phosphatic diathesis—that is, the occurrence of an excess of alkaline and earthy phosphates in the urine—may not make itself apparent to the eye. The alkaline phosphates may be present in an inordinate excess; and, as in the sulphuric diathesis, the sulphates may be immensely increased," etc. (Lectures on Digestion, Respiration, and Secretion, *Medical Times and Gazette*, March 27th, 1852.)

Now, in these cases, what is observed is, that a greater proportion of certain constituents is excreted in the urine than occurs in perfect health. The different physiological conditions under which an excess of many is produced are well understood, and the result cannot be referred to any peculiar habit or diathesis. If we speak of the *sulphuric acid diathesis*, we must, of course, admit the *urea diathesis;* for usually, when the sulphates are in excess, a corresponding increase in the proportion of urea exists. On the same principle, we might speak of the *extractive diathesis* and the *water diathesis.* It would be quite as fair to talk of the *carbonic acid diathesis* when an increased proportion of carbonic acid was exhaled, etc.

Many of the above remarks will apply to the so-called *oxalic diathesis*. The presence of oxalate of lime, and the increase of those materials which exist in health, depend upon the action of well known laws, and result as the natural consequence of confinement, exposure to cold, particular kind of food, etc. No peculiar diathesis can be discovered in persons who pass urine having these characters: in fact, in the majority of cases, the alteration is only of temporary duration; and it therefore seems to me that the term *diathesis* is quite inapplicable. We may perhaps speak of the *gouty diathesis*, and of the *rheumatic diathesis*, with more propriety, because here there certainly is a peculiarity of constitution, which may be transmitted from parent to offspring, and which is characterised by the invariable presence of certain morbid actions which exist in the conditions familiar to us under the terms *gout* and

rheumatism. But of the actual state of the blood, and condition of the vital processes, which lead to the symptoms with which we are so familiar, we really know very little; so that it seems to me better, even in this case, to discard the terms, and say that a patient suffers from attacks of gout or rheumatism, instead of attempting to hide our ignorance of the essential nature of these morbid states under a learned term, the meaning of which cannot be well defined. I shall venture, then, to discard altogether the use of the word *diathesis* in the discussion of morbid states of the urine; and I think we shall be in a better position to investigate the causes of changes occurring in the secretion in disease, and to study the manner in which urinary deposits are formed.

I propose to draw your attention to the subjects in the following order:—First, cases in which there is excess or deficiency of any of the normal constituents of urine. Secondly, I shall refer to the characters of certain soluble substances in the urine in disease, which are never met with in a state of health; and then I propose to give a brief sketch of the anatomy and physiology of the kidney, including some of the most important morbid changes which occur in the organ, especially with reference to the formation of casts of the uriniferous tubes. This leads us to the subject of *urinary deposits;* and we shall consider the various plans for collecting and preserving them, and the characters of the extraneous matters which are often present accidentally. The insoluble substances constituting *urinary deposits* will be divided into—

a. Substances floating on the surface of the urine, or diffused through the fluid.

b. Light and flocculent deposits.

c. Dense and opaque deposits.

d. Granular and crystalline deposits.

The subject of *urinary calculi* follows next in order; and lastly, I propose to draw your attention to the apparatus in use for the microscopical and chemical examination of urine,

urinary deposits, and calculi; the volumetric analysis of urine; and other points of practical importance in investigating the characters of the secretion.

Let us now proceed to the consideration of specimens of urine, in which an excess or deficiency of the normal constituents of the secretion is observed.

Excess or Deficiency of Water and the Organic Constituents.

Water. The varying quantities of water removed from the body, in different physiological states of the system, have been already referred to. We are all familiar with the relations existing between the functions of the skin and intestinal canal and the kidneys. The same laws hold in disease. If the kidneys be diseased, and the intestinal canal, the skin, and the respiratory apparatus, be tolerably healthy, the latter to some extent fulfil the work of the kidneys. In skin-diseases, and in certain affections of the intestinal canal, increased work is thrown upon the renal apparatus. In the treatment of such cases, the practitioner must bear in mind the existence of these relations. There are, however, certain affections in which the quantity of water removed from the body is greatly increased. In various hysterical and other emotional affections, large quantities of pale urine, containing but a small quantity of solid matter, are frequently voided. Some persons habitually pass very dilute urine, which is not very easily explained, but is probably to be looked upon as an individual peculiarity, corresponding to the constant sweating, and to the unusual amount of action of the alimentary canal, occasionally met with in persons who enjoy good health. It has been already remarked, that within certain limits water increases the disintegration of tissue; and when a large amount of fluid is taken, the total quantity of solids removed in the urine is greater than in health. When the solids as well as the water are greatly increased in quan-

tity, we should be led to fear the existence of diabetes. An unusual quantity of urine, of very high specific gravity, and therefore containing a large amount of solid matter, is almost characteristic of this condition.

Diabetes Insipidus. The majority of the so-called instances of diabetes insipidus are cases in which there is great thirst, and a large amount of water is removed from the kidneys daily (*diuresis*); but the total quantity of solid matter is not above the normal standard. In a few of the cases recorded, it would appear that the latter is also much increased; but these must be very rare. There is no sugar in these cases. I have seen cases in which the quantity of water passed as urine was two or three times as great as that said to have been taken in the food; but I firmly believe that deception was practised, and that the patient got water by stealth. Of this condition, termed by some authors *diabetes insipidus*, I know but little. I do not think that it is sufficiently well characterised to give to it the title of a distinct disease; I believe it depends merely upon a large quantity of water having been taken. The following analysis represents the composition of the urine in one of these cases. It was obtained from a man aged 45, in King's College Hospital, under Dr. Todd, who was passing about eleven pints of urine *per diem*, while he was drinking about thirteen pints of liquid. Reaction feebly acid; specific gravity 1002·8.

Analysis 1.

			In 24 hours.
Water . . .	995·91		
Solid matter . .	4·09	100·00	394
Organic matter .	2·79	68·22	268
Fixed salts . .	1·30	31·78	125

The quantity of urea excreted in twenty-four hours in this case was very small, which confirms the observation of Bischoff, that the ingestion of a large quantity of water diminishes the excretion of urea. At first, the total quantity passed in

twenty-four hours is above the average, because much is washed out from the tissues by the large quantity of fluid; but afterwards it falls, because less is formed in the organism than under ordinary circumstances. The proportion of inorganic salts to the organic constituents of the urine is very high, though the total quantity is less than is passed in health.

Deficiency of Water is, in the great majority of cases, associated with an abnormal quantity of solid matter. The ingredient which is usually in excess, and to which the urine owes its great density, is urea; so that urine of this character will be more conveniently considered presently. There are cases in which a very small quantity of urine, containing but a small percentage of solid matter, is passed; but in these *albumen* is generally present, and they will be considered under this head. When the total amount of urine is very small, and the secretion contains but little solid matter, the secreting structure of the kidney is generally much impaired; and it is therefore necessary to endeavour to make other organs take part in eliminating from the system substances which normally pass off in the form of urine.

Increased Acidity of Urine. The causes of the reaction of healthy urine have been already considered in Lecture I, and it is therefore unnecessary to pursue this part of the subject farther. Vogel states that, in chronic and acute diseases, the quantity of free acid is diminished for the most part. In many cases of pneumonia and rheumatic fever, however, the quantity of free acid is much greater than in health.

A highly acid condition of the urine, persisting for a long period of time, may cause the precipitation of uric acid, and so lead to the formation of a calculus. Acid urine not unfrequently causes irritable bladder, and excites other morbid actions. In most cases, the salts of the vegetable acids (citrates, acetates, tartrates) will be found more efficient in counteracting this acid state of the urine, than alkalies or their carbonates, and are less likely to interfere with the digestive

process. There are, however, low conditions of the system in which the acid state of the urine, and a tendency to the deposition of uric acid in large quantity, are not relieved by alkalies; on the contrary, such cases are often much benefited by an opposite plan of treatment—tonics and the mineral acids before meals, a nourishing diet, with a moderate supply of simple stimulants with a little alkali, or with alkaline waters. Pepsine is often of great use in these cases. Many of them seem to be intimately connected with impaired digestive power. The acid state of the urine may then depend upon very different conditions of the system, and these must be carefully considered in each individual case before any plan of treatment is suggested.

An *alkaline condition* of the urine may be due to several causes, and requires, therefore, to be treated on different plans. The connexion between an alkaline state of the urine, depending upon fixed alkali, and the secretion of a highly acid gastric juice, has been already referred to. In such cases, attention must be paid to the state of the digestive process; and, when this is set right, the urine will regain its normal characters. Dr. Bence Jones (*Medico-Chirurgical Transactions*, vol. xxxv) alludes to three cases of dyspepsia with vomiting of a very acid fluid (two of them rejecting sarcinæ), in which the urine became alkaline from the presence of fixed alkali when the quantity of acid set free at the stomach was very great; but, when this was small, the reaction of the urine was acid. It must, however, be borne in mind that the very acid nature of the materials rejected in many cases of vomiting, and especially in cases of sarcina ventriculi, arises, not from the secretion of an acid fluid by the glands of the stomach, but from the decomposition or fermentation of the food when acids are developed, among which may be mentioned acetic, lactic, and butyric acids. At the same time, there can be no doubt that, in many cases of dyspepsia, the feebly acid or alkaline condition of the urine arises from the secretion of

an abnormal amount of acid by the stomach. "The degree of the acidity of the urine may, to a certain extent, be regarded as a measure of the acidity of the stomach." (Dr. G. O. Rees, *Lettsomian Lectures*, 1851.)

Dr. Rees has drawn attention to a large class of cases in which he explains the alkaline condition of the urine as follows:—Urine which is highly *acid* at the time of its secretion, irritates the mucous membrane of the bladder, and causes it to secrete a large quantity of *alkaline fluid*. This mucous membrane in health secretes an alkaline fluid, to protect its surface, just as occurs in the case of some other mucous membranes. Under irritation, more alkaline fluid than is just sufficient to neutralise the acid of the urine is poured out; and hence the urine, when examined, is found to have a very alkaline reaction. In such cases, this highly alkaline condition is removed by giving liquor potassæ or some other alkali, or a salt of a vegetable acid which becomes an alkali in the system. The urine is not secreted so acid, and therefore does not stimulate the mucous membrane to pour out so much alkaline fluid. I know no observations to disprove Dr. G. O. Rees' explanation of the fact that, in some cases, *alkalies cause the urine to become less alkaline, or even restore its acid reaction ;* yet one would hardly expect, if this be the true explanation in cases generally, that the natural reaction of urine would be acid. If there was danger of the healthy mucous membrane suffering from the contact of a fluid only a little more acid than that destined to be continually touching it, should we not expect it to have been of such a character as to resist this action like the mucous membrane of the stomach, instead of being excited to secrete a fluid of such a nature as might lead to its own destruction? Again, the mucous membrane of the bladder bears very well the contact of acid fluids which are sometimes injected; and patients sometimes for years pass intensely acid urine, without the secretion of this excess of alkaline fluid from the mucous membrane.

Nitric Acid in the Urine. Dr. Bence Jones (*Philosophical Transactions*, 1851, p. 399) has been led to the conclusion that ammonia, in its passage through the organism, gives rise to the production of a certain quantity of nitric acid, which is eliminated in the urine. He found that the acidity of the urine was not diminished by giving large quantities of carbonate of ammonia; and that, in some instances, the acid reaction seemed to be increased. While tartrate of potash soon rendered the urine alkaline, this effect was not produced by the corresponding salt of ammonia.

The following test, suggested by Dr. Price, was employed for the detection of the nitric acid, in preference to the indigo test. By this plan, one grain of nitrate of potash dissolved in ten ounces of urine was detected with the greatest certainty. From four to eight ounces of urine were mixed with half an ounce of strong and pure sulphuric acid, free from nitrous acid. Two-thirds of the mixture were distilled over; and, after being neutralised with pure carbonate of potash, the distillate was evaporated to a very small bulk. From a drop, to half the residue, was mixed with the following test-solution. To a solution of starch, a drop or two of a solution of iodide of potassium, specific gravity 1052, and very dilute hydrochloric acid, specific gravity 1005, were added. If nitric or nitrous acid is present, the iodine is set free, and a blue iodide of starch is at once formed.

Another portion of the residue was placed in a basin, and a very small quantity of indigo, with excess of sulphuric acid, added. If nitric acid was present, upon applying heat for a few minutes, the colour of course disappeared.

From numerous experiments, varied in many ways, Dr. Bence Jones came to the conclusion that ammonia in the organism is partly converted into nitric acid. The nitrogen of the air also, in ordinary combustion, unites with oxygen to form nitric acid. Urea and caffein, and other substances containing nitrogen, give rise to the formation

of a small quantity of nitric acid. Although Lehmann has failed to confirm these results, he has not, I think, succeeded in shaking the evidence in favour of this view.* Dr. Bence Jones brings forward several cases of healthy persons whose urine did not yield a trace of nitric acid; but, three or four hours after they had taken carbonate of ammonia, evidence of the presence of the acid was afforded by the starch and also by the indigo test. After twelve hours, only a trace could be detected; and, in twenty-four, even this ceased to be perceptible. The urine was examined in precisely the same manner in every case. I think, therefore, we may conclude that a small amount of ammonia in the organism is converted into nitric acid; and it is not improbable that, under certain circumstances, the quantity of nitric acid formed in this manner may be very much increased.

Ammonia. Numerous experiments seem to show that in health a small quantity of ammonia escapes in the urine. Neubauer has conclusively proved that certain ammoniacal salts pass through the organism, and may be detected in the urine unchanged. Ammonia, as is well known, is very easily produced by the decomposition of the urea; but it is almost certain that a small quantity passes into the urine from the blood, independently of that derived from this source.

In disease, the quantity of ammonia present in the urine is often so great as to be smelt all over the room in which the patient lies; but in these cases the ammonia arises from the decomposition of the urea after the urine has left the bladder, and in some it is decomposed even while it yet remains in this viscus.

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* Professor Lehmann attributed the reaction on the iodide of potassium to the presence of *sulphurous acid.* Jaffé performed some experiments in Lehmann's laboratory, and obtained sulphurous acid but no nitrous acid from healthy urine and from urine passed after taking ammoniacal salts. Dr. Bence Jones has subsequently repeated his experiments, and finds that Jaffé's experiments do not invalidate Price's test for nitrous acid as Lehmann supposed. (*Proceedings of the Royal Society*, vol. vii, p. 94.)

It is doubtful if a large amount of ammonia under any circumstances accumulates in the blood afterwards to be excreted in the urine, as it is probable that, if formed, it would escape more rapidly from the lungs or intestinal canal. The doctrine that the coma occurring as a sequel to many cases of kidney-disease, depended upon the accumulation in the blood of ammonia produced by the decomposition of urea, was originally put forward by Frerichs. In some of these cases of renal coma, ammonia is present in abnormal quantity. In others, neither urea nor ammonia can be discovered in the blood, while sometimes urea can be detected without difficulty. Let me allude briefly to two or three cases, in which urea was discovered. Half an ounce of blister serum from a man suffering from renal coma yielded ·54 gr. of nitrate of urea. The patient died shortly afterwards, and urea was detected in the blood and in the brain substance. In another insiance, it was detected in the serum of a blister from a man who had had one epileptic fit, depending upon renal disease. In the case of a boy, aged 18, who suffered from epileptic fits, I also detected it in blister serum; as well as in eight ounces of serum from a man suffering from acute dropsy of a week's duration; and I might refer to others in which I obtained undoubted evidence of the presence of urea. There are many other cases of the same character in which I failed to detect urea, or ammonia resulting from its decomposition.

I have several times examined the breath of such patients, without being able to obtain indications of a larger quantity of ammonia than is afforded by healthy persons. I think, therefore, that we must admit that there are many cases of the so called *uræmic poisoning* which have not yet been satisfactorily explained. It may, however, be urged that, in many cases, although ammonia was formed, it might have been rapidly eliminated from the skin or intestinal canal, so as to escape detection. Bernard and Barreswil have performed some experiments which prove that, after extirpation of the kidneys,

urea escapes into the intestinal canal in the form of an ammoniacal salt; and they found that it could not be detected in the blood in less than from twenty-four to forty-eight hours after the operation, when the animal had become weak and exhausted.

Dr. William Budd has detected urea in the blood and blister serum (from three ounces to six drachms) of several cases of gout. (*Med. Chir. Trans.*, vol. xxxviii, p. 212.)

On detecting Urea in the Blood or Serum. The urea may be detected by concentrating the serum, after adding a few drops of acetic acid, and extracting with strong alcohol, or the fluid may be evaporated to dryness and the dry residue treated with boiling alcohol. The alcoholic solution is evaporated to dryness, treated with a drop of distilled water, and two or three drops of strong nitric acid allowed to fall into the syrupy solution. If urea be present, crystals of the nitrate

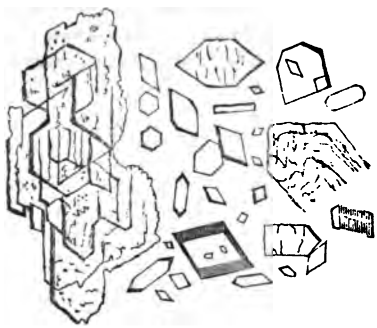

Fig. 2.—Nitrate of Urea × 215.

of urea are formed, and may be readily distinguished by microscopical examination.

On detecting Ammonia in the Breath. The method of examination which Dr. Richardson recommends is the following. An instrument in the form of a straight breast pump is employed to breathe through; a drop or two of hydrochloric acid

is placed in the bulb, and a perfectly clean slip of microscope glass placed across the trumpet extremity of the tube, and secured by an India-rubber band. The alkali, as it passes over the

Fig. 3.—Crystals of Chloride of Ammonium obtained by breathing over hydrochloric acid.

bulb, combines with the acid, but some of the acid and alkaline vapours pass over together and condense on the microscope glass. As this becomes dry, crystals are formed. In health, traces of ammonia are always found in this manner.

Urea. From what has been already said with reference to the variations in the proportion of urea secreted, under different circumstances, in a state of health, it will be inferred that, in disease, the quantity of this constituent varies greatly. The total amount formed in a given time may be much greater or less than in health; and the proportion which this substance bears to the other organic constituents varies greatly in different cases.

Excess of Urea. The term "excess of urea" is not applied to those cases in which the total quantity excreted in the twenty-four hours is much greater than in health; but a

specimen of urine which yields crystals of nitrate of urea when an equal bulk of nitric acid is added to it in the cold, without having been previously concentrated, is said to contain "excess of urea". The quantity of urea dissolved in the fluid is so great that a nitrate of urea is formed, and crystallises just as if the urine had been concentrated by evaporation. This result may be brought about in several ways. In cases in which but a small quantity of fluid is taken in proportion to the urea to be removed—when an unusually large amount of water escapes by the skin and other emunctories—and in cases in which an unusual amount of urea is formed in the organism, we shall frequently find excess of urea in a specimen of the urine.

There is, however, another class of cases in which the urine often contains this excess of urea; and at the same time more than the healthy amount is excreted. The patient is weak, and grows thin, in spite of taking a considerable quantity of the most nutritious food. He feels languid, and indisposed to take active exercise. In some cases, digestion is impaired; in others, the patient eats well, experiences no pain or uneasiness after food, and perhaps has a good appetite. Sometimes there is lumbar pain. It would seem that much of the albuminous material in the blood, instead of being applied to the nutrition of the tissues, becomes too rapidly converted into urea, and is excreted. The waste of the tissues is not properly repaired, and the patient gets very thin. To refer these symptoms to the existence of a particular diathesis, appears to me no explanation of the nature of the case. The pathology of these remarkable cases has not yet been satisfactorily investigated. Mineral acids, rest, shower-baths, and good air, often do good; but some of these patients are not in the least benefited by remedies, and they continue for years very thin, passing large quantities of highly concentrated urine, while the appetite remains good, and they digest a considerable quantity of nitrogenous foods. I am now trying, in one of these cases, which has resisted the usual plans of treatment, the effect of

pepsine, with diminished quantity of meat, and a larger amount of farinaceous food. The condition often lasts for some years, and then the patient's health improves, and he gets quite well.

Dr. Golding Bird has drawn attention to the frequency of the occurrence of excess of urea with oxalate of lime. The quantity of oxalate of lime, however, is in all cases so very small that it is hardly possible to believe that the formation of this substance can be very important. We shall see that oxalate is one of the commonest urinary deposits; that it results from decomposition; that there is no reason for believing it to be indicative of any peculiar diathesis or habit of body. Excess of urea affords no explanation of the presence of oxalate of lime, nor this latter of urea. Each condition may exist without the other. *Cæteris paribus*, we should expect to find oxalate of lime most frequently present in specimens of highly concentrated urine.

Excess of urea is frequently found in the urine of persons suffering from acute febrile attacks. It is very common in cases of acute rheumatism, and is often met with in pneumonia and acute febrile conditions generally. In England, we meet with many of these cases; but, on the continent, they appear to be so rare that many authorities seem to doubt the truth of what English observers have stated with regard to this point. Lehmann, I think, states that he had not seen a case in which crystals of nitrate of urea were thrown down upon the addition of nitric acid, without previous concentration.

The amount of urea excreted is often very great. Vogel mentions a case of pyæmia in which 1235 grains of urea were removed in the course of twenty-four hours. Dr. Parkes obtained as much as 885 grains in a case of typhoid fever. These quantities are very great, if the patients do not exceed the average weight of adult men; but, unfortunately, their weight was not recorded.

Urine containing excess of urea is generally perfectly clear,

of rather a dark yellow colour, and of a strong urinous smell. Its specific gravity is about 1030, and it contains generally 50 or 60 grains, or more, of solid matter per 1000. At ordinary temperatures, an aqueous solution must contain at least 60 grains of urea per 1000, to form crystals of the nitrate upon the addition of nitric acid without previous evaporation; 50 grains of urea per 1000 hardly gave the slightest precipitate after the lapse of a considerable time. It would seem that the salts, extractive matters, etc., in urine, cause the crystallisation of the nitrate when even a smaller quantity of urea is present. It should be mentioned, that the above experiments were performed in the summer, in very hot weather. In one case, in which the urea readily crystallised on the addition of nitric acid, the urine had a specific gravity of 1028, and contained—

Analysis 2.

Water	940·18
Solid Matter	59·82
Organic Matter	50·57
Fixed Salts.	9·25

Much has already been said with regard to the circumstances which cause a diminished quantity of urea in health (page 23). I may remark here, that Dr. E. Smith holds that tea and coffee excite respiration and increase the quantity of carbonic acid; that tea increases waste, and excites every function in the body; and that it is, therefore, injurious to those who are not well fed. These conclusions are at variance with the results of the laborious investigations of Dr. Böcker, who found that tea caused a diminution in the quantity of perspiration, urea, and the fæces. He states that it does not influence the amount of carbonic acid formed, nor the frequency of the pulse or respiration; and that, when the diet was insufficient, tea prevented the loss of weight being so great as it would have been otherwise.

In chronic disease of the kidney, the urine is of very low specific gravity, and but a very small proportion of urea is excreted in the twenty-four hours. This arises from the altera-

tion in the gland-structure, and the amount of urea separated may be regarded as a rough indication of the extent of the organ involved. In some cases, the morbid condition affects the whole structure; but in others the greater part of the kidney remains healthy. In the latter case, a fair amount of urea will be excreted; and, although the urine contains albumen, the case may be looked upon as a hopeful one. Sometimes the quantity of urea excreted is very small. A lady suffering from an ovarian tumour only excreted 75 grains of urea in 200 fluidrachms of pale faintly alkaline urine in the course of twenty-four hours. (Thudichum.)

In certain cases, urea almost entirely disappears from the urine, and is replaced by leucine and tyrosine. Frerichs mentions a case of acute yellow atrophy of the liver, in which only a trace of urea could be detected, while a very large quantity of leucine and tyrosine crystallised from the concentrated urine. (*Klinik der Leberkrankheiten. Erster band. Seite* 221.) In low forms of typhoid fever, the urine also frequently yields leucine and tyrosine in considerable quantity.

Colouring Matter. The variation of colour of the urine in disease is a matter of great interest; and, although the causes of the change, and the exact nature of the substances which give rise to the peculiar tints often observed, are not yet understood, still there are many valuable observations connected with this subject, some of which I propose to refer to in this place. The colour of urine depending upon blood-corpuscles will be discussed under the head of urinary deposits, and now I shall only refer to colouring matters formed in the body and excreted in *solution* in the urine. It should be observed, that pyrola, sumach, and some other substances, alter the colour of the urine. Dr. Hughes mentions cases of dark pigment occurring in the urine of patients taking iodine. These cases, however, are of course not dependent upon morbid changes in the organism.

The principal substance to which the colour of urine is due

is probably derived from the blood corpuscles, which are continually undergoing disintegration. This colouring matter becomes altered under different conditions. Much of it is converted into a colouring matter which is separated in the urine, and termed uræmatine (uraphæin, hæmaphine), which is soluble in ether, and, according to the researches of Dr. Harley, is a resinous body, agreeing in some of its characters with the biliary resins.

It is impossible to estimate directly the quantity of the colouring matter present; but Professor Vogel calculates the proportion by ascertaining how much water may be added to the urine to produce a particular tint, which is arbitrarily fixed as the unit of comparison. The quantity of this substance affords an indication of the activity of the disintegration of the blood-corpuscles. In typhoid fever and many other conditions, this disintegration takes place to such an extent as to produce an anæmic condition. In many acute diseases, a very large amount of colouring matter occurs in the urine. In the same cases, urea is not unfrequently present in excess, as in pneumonia, typhus fever, acute rheumatism, etc. The formation of the urine-pigment is intimately connected with the action of the liver; and, as is well known, in diseases of this organ, the urine is frequently very high coloured. Of course, I am speaking of colour independent of the colouring matter of the bile. The colour of the urine in diseases of the liver has been often remarked by physicians practising in India; and quite recently my friend Dr. Payne has made some interesting observations on this point, which will be found in the *Indian Annals of Medical Science* (Calcutta, Sept. 4th, 1858). In order to detect the colouring matter, Dr. Payne boils the urine, and then adds a drop of nitric acid. Various shades of colour are produced, but at last the mixture becomes of a ruby red. Deficiency of colouring matter occurs in many cases of anæmia. Sometimes the urine is as pale as water.

Heller's observations upon the colouring matter have been

alluded to. This observer found more uroxanthine (which may be decomposed into indigo blue or uroglaucine, and indigo red or urrhodine) in the urine of persons suffering from diseases of the serous membranes, of the kidneys, and of the spinal marrow, than in the healthy secretion. Schunk, who first separated indigo blue and indigo red, and showed their identity with Heller's uroglaucine and urrhodine, found as much uroxanthine or indican in healthy as in morbid specimens of urine, and he detected it in the urine of thirty-nine persons out of forty. The quantity of this colouring matter is exceedingly small. Schunk, by working on the urine of two persons for several weeks, only obtained one grain of indigo blue.

Fig. 4.—Uroglaucine from the Urine. *a.* Small collections of a pale blue colour, like Prussian blue. *b.* A darker mass, formed of small spherical masses. *c.* Crystals of uroglaucine, of a deep purple or violet colour.

My friend Dr. Eade of Norwich sent me a specimen of urine containing a deposit of uroglaucine obtained from a man eighty-three years of age (*Archives of Medicine*, vol. i, p. 311). Some of these crystals are represented in Fig. 4, and in Fig. 5 are shown some crystals of indigo.

Tests. When sulphuric acid is added to urine containing much uroxanthine, a dark blue colour is produced. The mode of employing this test recommended by Dr. Carter, who has made some important investigations on this subject (*Edinburgh Medical Journal*, Aug. 1859), is as follows:—Urine is poured

Fig. 5.—Crystals of Indigo. *a.* Obtained by sublimation. *b.* Larger crystals of the same. *c.* Small crystals of indigo in fluid.

into an ordinary test-tube, to the depth of half an inch; one-third of its volume of sulphuric acid, specific gravity 1830, is then allowed to subside to the lower part by letting it fall gradually down the side of the tube; the acid and urine should then be mixed well together. The colour produced varies from a faint pink or lilac to a deep indigo blue colour.

Is uroxanthine to be considered an ingredient of normal urine? As Schunk found this substance in the urine of thirty-nine healthy persons out of forty, and Dr. Carter recently detected it in the urine of three hundred persons (some suffering from disease, others healthy), we may, I think, regard it as a constituent of healthy urine. Dr. Carter has detected it in the blood of several patients—in fact, in every case

in which he sought for it. It was also found in the blood of the ox.

Process. The serum was poured off, and a strong solution of diacetate of lead added to it as long as a precipitate was produced. The mixture was then thrown upon a linen filter, and the filtrate was brought to the boiling-point as rapidly as possible in a small flask, in order to coagulate the albumen that had not been precipitated by the lead salt. The solution was then filtered through paper into a vessel placed in cold water; and, when the liquid was cold, a slight excess of caustic ammonia was added. The deposit thus produced, when collected and slightly washed with water, was of a faint yellowish buff colour. The moist precipitate, upon being treated with excess of concentrated sulphuric acid, developed a distinct red colour, owing to the formation of indigo red. The colour was taken up by ether, after the acid had been neutralised by ammonia. The oxide of lead precipitate, from an ounce and a half of blood-serum from a man, forty-three years of age, suffering from acute pleurisy, struck with the acid a distinct lavender colour, which in half an hour passed into a deep red purple. (*On Indican in the Blood and Urine*, by J. A. Carter, M.D.; *Edinburgh Medical Journal*, August 1859.)

The Colouring Matter of the Blood-Corpuscles may be present in urine without any corpuscles. In many cases, owing to the rapid disintegration of blood-corpuscles, the serum is highly coloured. It is probable that the dissolved colouring matter may be sometimes excreted by the kidneys. As Dr. Thudichum has suggested, blood may escape from the vessels into the tubes of the kidney; and the corpuscles entangled in casts may gradually become disintegrated, and their colouring matter be dissolved by the urine afterwards. The *hæmatoglobuline* coagulates at a temperature of about 200°, while *albumen* is precipitated at a temperature a little above 140°. In this manner these substances may be distinguished.

There can be little doubt that both the colouring matter of

the bile and of the urine are derived from that of the blood-corpuscles. The precise manner in which the change is accomplished has not yet been demonstrated, but it is not improbable that careful observations upon the urine in disease would lead to a solution of this question. That bile-acids and their salts were powerful solvents of blood-corpuscles, was long ago proved by Hühnefield, Plattner, and Simon; and it has lately been shown by Kühne that, by the action of the colourless biliary acids or their salts upon the blood-corpuscles, bile-colouring matter is produced. The bile-acids themselves are not converted into the colouring matter, as Frerichs held; for they pass through the system unchanged. Now, in certain cases where these processes are deranged, it is very probable that the blood-corpuscles are disintegrated in abnormal quantity, and rapidly converted into pigment, which escapes in the urine. The complicated mutual reactions which would ensue when varying proportions of biliary acids, hæmatine, and oxygen, are presented to each other in the living blood, would fully account for the different characters and tints which the colouring matters in urine assume in various cases. Professor Vogel alludes to a case in which the colour of the urine became very dark after the inhalation of arseniuretted hydrogen. Some experiments were made upon a dog, and it was found that the dark colour was due to the disintegration of blood-corpuscles. Albumen was present, but no blood-corpuscles could be detected. A similar disintegration of blood-corpuscles seems to take place in typhoid fever, and in several other diseases.

Dr. Marcet describes a black pigment which was present in the urine of a child. After the addition of an acid, some black flocculi were deposited. Professor Dulk gives a case in which a black deposit was separated from the urine by filtration. Other examples are recorded by Dr. Hughes. In three of these cases, creasote had been taken internally; and in two, tar had been applied externally. In one case, a dense black precipitate was thrown down by heat and nitric acid, which

was examined by Dr. Odling, who found that, by exposure, it became converted into indigo blue. He draws attention to the close alliance of indigo to the creasote series of compounds, and suggests that, in the above cases, it was derived from the tar or creasote. (Quoted in Dr. Golding Bird's work, fifth edition, edited by Dr. Birkett.)

Uric Acid and Urates are present in certain proportion in healthy urine, but in disease a large increase is very frequently observed. These substances form urinary deposits, either from existing in too large a proportion to be dissolved in the urine when cold, or, as is probably the case in the majority of instances, from the development of an acid in the urine, which causes them to be precipitated from their solutions. We shall consider the microscopical characters of these bodies under the head of urinary deposits. In many acute febrile diseases, the proportion of uric acid is increased, and the period of resolution of the inflammation is marked by diminished frequency of the pulse and respiration, by a fall in the temperature, by free perspiration, and by a very abundant deposit of urates. In health, from 5 to 8 grains of uric acid are excreted in twenty-four hours; but, in some acute diseases, the proportion may amount to twenty grains. In a case of fever, Dr. Parkes found that 17·28 grains of uric acid were excreted in twenty-four hours. Urate of soda is very readily caused to deposit crystals of uric acid. If the amorphous deposit be merely dissolved by warming the urine, the urate often becomes decomposed; and, as the solution cools, crystals of uric acid are deposited. In some cases, the quantity of uric acid held in solution is so great that, upon the addition of a drop of nitric acid to the urine, an abundant amorphous precipitate, exactly resembling albumen, is formed. Such a precipitate has many times been mistaken for albumen (see *Albuminous Urine*), and, even if examined under the microscope immediately after it is formed, its nature cannot be made out; but if it be allowed to stand for some time, the amorphous particles gradually increase in size, and

assume the well known crystalline forms of uric acid. The instances in which I have met with urine exhibiting these characters have almost all been cases of liver-disease. Although the reaction is acid, no precipitate takes place upon the application of heat, which at once distinguishes urine of this character from albuminous urine.

The presence of an abnormal quantity of uric acid in the urine shows that more of this substance or its salts is formed in the blood than in health. It would appear that, in consequence of certain conditions, a large proportion of the uric acid resulting from the disintegration of albuminous substances is not further oxidised and converted into urea, but combines with ammonia, soda, or lime, forming urates of these bases. In gout, the presence of uric acid has been detected in the blood by Dr. Garrod. *During* the attack there is less in the urine than in health; but *after* it is over, a large quantity of uric acid and urates are often carried off from the system in the urine.

In cases characterised by a tendency to the formation of much uric acid, the principal objects to be attained by treatment are, to favour the further oxidation of the uric acid formed, and to promote its solution and elimination from the blood as rapidly as possible. Good air and moderate exercise, with attention to the action of the skin, will fulfil the first object; and the solution and elimination of the urates will be encouraged by giving alkalies in solution in a considerable quantity of water.

The satisfactory change which in chronic gouty and rheumatic cases frequently ensues from following some of the much vaunted "systems", or going through a course of bathing in Germany or elsewhere, obviously arises from the increased action of the skin, and the improvement of the health generally, effected by the exercise, good air, simple diet, and temperance, wisely enforced in the establishments. If patients could be induced to retire to a pleasant

part of the country, where they could take moderate exercise and be free from mental anxiety, meet with agreeable society, live regularly, take small doses of alkalies, and soak themselves for an hour or two a day in warm water in which some carbonate of soda had been dissolved, they would receive as great benefit as by travelling hundreds of miles away, and at much less trouble and expense. I am convinced that there are many patients who would prefer to carry out such a simple plan, rather than submit themselves to all the useless routine and absurd formalities involved in many of the professed universal systems, such as homœopathy, hydropathy, etc., which cannot but be extremely offensive to their common sense, while they are claimed as converts and supporters of doctrines which they do not really believe in. There are many who, for the sake of the advantage they derive from the regular system of living, air, exercise, etc., express no disbelief in doctrines and propositions which they probably feel to be absurd, and which a little reflection must prove to be false.

In all such cases, the nature of the derangement of the physiological procesess should be carefully considered before any plan of treatment is adopted. We must ascertain in what points the condition differs from a healthy state, and then consider how the deranged actions may be restored. In such cases, it is obviously quite useless to attempt to relieve the patient by giving drugs, without enforcing attention to all the circumstances which are likely to improve the health. Neither will it be wise to attempt to treat the case as if the presence of the uric acid deposit were the most important symptom, for the reasons I referred to when considering the subject of diathesis. The physiological changes taking place in the organism generally must be attended to, and the patient must be instructed to employ those means which are likely to restore healthy action.

Hippuric Acid, as before mentioned, never forms a deposit.*

* Dr. William Budd in certain specimens of urine in cases of gout has observed a flocculent precipitate, which was found to consist of benzoic acid doubtless resulting from the decomposition of hippuric acid.

In diabetic urine, it is often found in large quantity, and seems to take the place of uric acid. It is also found in large quantity in the acid urine of fever patients (Lehmann). This fact is of great interest, when considered in connexion with the sugar-forming function of the liver, and the absence of hippuric acid in the organism in certain cases of liver-disease. Kühne has shown that no hippuric acid can be detected in the urine in cases of jaundice; and benzoic acid, which in health is converted into hippuric acid, escapes unchanged into the urine. There can, therefore, be little doubt that this substance is formed in the liver, whether by the action of glycin or glyco-cholic acid on benzoic acid, or some other substances, has not been determined.

To Lehmann's statement, that hippuric acid takes the place of uric acid in diabetic urine, there are many exceptions. I have found a considerable proportion of uric acid in the urine of many diabetic patients, and in several there was an abundant deposit of uric acid crystals.

Extractive Matters. The extractive matters present in healthy urine have been previously described; and I have mentioned that Dr. G. O. Rees has discovered in the urine, in certain cases, an extractive matter which has drained away from the blood, and which is distinguished by producing an abundant precipitate with tincture of galls. Now, although in many cases albumen exists in the same specimens of urine, this blood-extractive sometimes escapes without albumen; and thus the exhaustion and emaciation, in some obscure cases in which there is no hæmorrhage or escape of albumen, are accounted for. The method of testing urine supposed to contain this extractive matter has been described (page 428). The conclusions at which Dr. Rees has arrived are as follows:—

1. That whenever albumen was present in quantity in the urine, it was always accompanied by the extractives of the blood in large proportion.

2. That the cases in which the extractives of the blood were in the urine in large proportion, were generally those marked by debility.

3. That cases of anasarca with disease of the heart, and *unconnected with albuminuria*, also showed the extractives of the blood to be excreted by the urine in quantity.

4. That cases of chlorotic anæmia and hysteria give copious precipitates.

5. That when, in albuminuria, the albumen became deficient in the urine, which we know often happens in advanced cases, the blood-extractives also decrease in quantity.

6. That, in cases of anæmia, the proportion of blood-extractives observed in the urine diminished as the cure was proceeding, under the use of ferruginous tonics. (Lettsomian Lectures, *Medical Gazette*, 1851.)

In many cases where the urine contains an abnormal quantity of water, the proportion of blood-extractives is unusually great. In cases of kidney-disease, the relative proportion of extractive matter to the urea is very much greater than in healthy urine. It would seem that extractives merely filtered from the blood in certain cases, and that these substances might escape into the urine when the structure of the kidney was impaired; but that, for the separation of the urea, a healthy condition of the secreting structure is necessary.

The extractive matters are not capable of being converted, by further oxidation, into urea, carbonic acid, or ammonia; and must, therefore, be regarded as excrementitious substances. Scherer (*Würzburg Verhandl.*, B. iii, Heft 2, p. 180) found that the urea, salts, etc., in the urine of a madman who took no food, were very much diminished; while the extractive matters, although less than in healthy urine, were not diminished in nearly the same proportion as the other urinary constituents.

We know nothing of the circumstances under which the extractive matters may be formed in greater quantity than in

health, nor the effects which would result from their accumulation in the blood.

General Remarks on the Increase of the Organic Constituents of Urine. The circumstances under which these constituents are excreted in increased quantity have been already considered, and I propose now to call your attention to a few analyses of the urine in cases of disease in which this character is observed. In almost all forms of fever, in internal inflammations, in acute rheumatism, in many skin-diseases, and in all conditions in which there is increased action of the muscular system, the solids are considerably above the healthy standard; but the constituents do not suffer augmentation in an equal degree. In the conditions just referred to, the increase principally affects the organic matters. Sometimes all the ordinary constituents of the urine are excreted in increased proportion. Dr. L. Lehmann (*Archiv des Vereins für gem. Arb. zur Förderung der wissensch. Heilkunde. Erster Band, Seite* 521) has shown that immersion in the sitzbath, at a temperature of 48° to 60° Fahr., for a quarter of an hour, causes an increase in the quantity of urine, not only of the water, but also of the solid matter. The uric acid, the urea, and the fixed salts, were considerably increased. These results were obtained by estimating the constituents in urine passed during six hours on certain mornings when a bath was taken, and upon others when the observer did not bathe.

The mean of eight analyses of the urine passed during six hours, is as follows:—

	Mornings on which the bath was taken.	Mornings on which the bath was not taken.
Water	443·454 grams.	258·456 grms.
Solids	19·403 „	14·459 „
Urea	10·396 „	7·080 „
Uric acid	0·130 „	0·108 „
Fixed Salts	6·982 „	4.821 „
Volatile Salts and Extractive	1·89 „	2·45 „
Chloride of Sodium . .	5·814 „	4·319 „

In the following analyses of urine in cases of skin disease, the solid matter is increased; and it will be noticed that the proportion of fixed salts to the organic matters is greater than in health. In No. 4, the quantity of the extractive matter exceeds that of the urea.

In the second series of analyses of the urine in chorea, the principal points to be noticed are the large amount of solid matter, the increase being caused principally by the organic matters. In Analysis 11, the proportion of sulphates is seen to be increased. This increase of sulphuric acid is always observed in cases where the urea is increased.

Urine from cases of Skin Disease.

3. Urine from a case of eczema, with crusts over the whole body: specific gravity, 1025.

4. From the same patient on the following day.

5. From a case of eczema, in a boy, aged 18: specific gravity, 1033; acid, pale colour. Contains much uric acid.

6. From a case of ichthyosis, in a girl, aged 15: acid; specific gravity, 1032.

Urine from cases of Chorea.

7. From a girl, aged 10, recovering—after having been ill for several weeks. The urine contained a great number of Cayenne pepper crystals of uric acid.

8. From a girl, aged 12: specific gravity, 1033; no albumen; much deposit of urates.

9. From a girl, aged 14: specific gravity, 1035; acid; turbid from the presence of urates. Uric acid deposited in the urine=·46 per 1000 parts.

10. From a girl: specific gravity, 1030; acid; pale in colour.

11. From a boy, about 10 years of age.

12. From a boy, aged 14: acid; specific gravity, 1034·2.

Analyses.

	3		4		5		6	
Water	948·7		926·1		935·4		929·70	
Solid matter	51·3	100·00	73·9	100·00	64·6	100·00	70·30	100·00
Organic matter	27·9	54·6	51·70	69·97	47·01	74·17	48·35	68·77
Saline matter	23·4	45·40	21·20	30·03	16·69	25·83	21·05	31·20
Urea			24·03	32·51				
Extractives			27·21	36·82			48·35	68·77
Uric acid			·46	·62				
Alkaline salts	23·4	45·4	21·23	28·72	16·69	25·83	21·05	31·2
Earthy salts			·97	1·31				
Chloride of sodium . .					3·99	6·17	1·74	2·47
Sulphates					9·45	14·62		
Phosphoric acid . .					2·64	4·08		

Analyses.

	7		8		9		10		11		12	
Water	918·75		917·90		930·4		936·8		922·60		915·44	
Solid matter	81·25	100·00	82·10	100·00	69·6	100·00	63·2	100·00	77·40	100·00	84·56	100·00
Organic matter	66·53	82·05	68·50	83·45	51·95	74·65	48·75	77·14	50·79	78·55	65·68	77·68
Saline matter	14·62	17·95	13·60	16·55	17·65	25·35	14·45	22·86	16·61	21·45	18·88	22·32
Urea	30·09	37·03	41·10	50·06	25·33	36·39	29·78	47·12	34·29	44·30	64·69	76·50
Extractive matter	35·27	43·40	27·4	33·37	26·16	37·58	18·52	29·30	26·21	33·85		
Uric acid	1·27	1·5			·96	1·30	·45	·71	·29	·38	·76	·89
Urate of soda											·43	·50
Alkaline salts	13·53	16·65	12·83	15·62	17·16	24·94	13·69	21·66	16·07	20·76	18·88	22·32
Earthy salts	1·09	1·3	·77	·93	29	·41	·76	1·20	·54	·69		
Chloride of sodium									3·35	4·32	2·78	3·29
Sulphuric acid									3·54	4·57	5·81*	6·87*
Phosphoric acid									1·17	1·51		

* Sulphate of soda.

Excess or Deficiency of the Inorganic Constituents.

In disease, the inorganic salts vary greatly in quantity. Sometimes the saline constituents are very deficient. This deficiency may depend upon the nature of the food, or it may be due to the *formation* of a diminished proportion of some of the salts in the organism. The sulphates, and the phosphates in part, being formed in the body, will vary under many circumstances.

In some conditions of the system, when much disintegration of tissue takes place, a greater quantity of sulphur and phosphorus is oxidised, and the corresponding acids are formed in unusually large proportion, and excreted in the urine.

In certain inflammatory conditions of the system, it would appear that the chloride of sodium, being required at the seat of these changes in considerable quantity, is prevented from passing off from the system in the urine. In certain cases of disease of the kidney, it is important to notice if the proportion of the saline constituents to the organic matter is very much increased. In some states of renal disease, in which the secreting structure of the kidney is so much impaired that the separation of urea and organic matter is very much interfered with, a proportion of saline matter considerably larger than is present in the urine in health, escapes.

Let me now draw your attention to some of the most important variations in the excretion of saline matter in disease.

Chloride of Sodium. The fluctuations observed in the quantity of common salt excreted in the urine are very great even in health. The circumstances which affect the proportion of chloride of sodium are very numerous, and these are greatly increased in disease. It was found by Redtenbacher, many years since, that in pneumonia the quantity of chloride in the urine gradually decreased as the inflammation advanced; and that in many instances, when the lung became hepatised, not a trace could be detected in the urine. Some

years ago, I determined quantitatively the amount of chloride in the urine from day to day in cases of acute pneumonia, and the following case illustrates very well the changes which occur in the urine in this affection.

The patient was a plasterer, aged 24, and was under the care of Dr. Budd. On the third day of the disease, there was dulness two inches below the left mamma in front, and behind over the space below the spine of the scapula. Bronchial breathing and bronchophony were audible over the lower angle of the scapula. Expectoration viscid, frothy, and slightly rusty; pulse 144, small and weak; respirations, 52.

On the fourth day of the disease, bronchial breathing and bronchophony were more distinct. Pulse, 116; respirations, 28. He was treated with small doses of antimonial wine, and was put upon milk diet and beef-tea. Turpentine stupes were applied to the chest. He progressed favourably, was convalescent within three weeks after the commencement of the attack, and was discharged well in little more than four weeks.

13. *Fourth day* of the disease. Urine high coloured; acid; specific gravity, 1017; contained a little albumen.

14. *Fifth day*. Acid; specifi; gravity, 1013; natural colour.

15. *Sixth day*. Acid; specific gravity, 1016; pale; still contained a trace of albumen.

16. *Tenth day*. Acid; specific gravity, 1022; no albumen.

17. *Twenty-second day*. Acid; specific gravity, 1016; pale; no albumen.

Analyses.

	13		14	15	
Water . .	956·60		957·40	954·00	
Solid matter .	43·40	100·00	42·60	46·00	100·00
Organic matter	40·28	92·82		44·64	97·05
Fixed salts .	3·12	7·18		1·36	2·95
Chloride of sodium	0		traces	0	

	16		17	
Water . . .	955·00		968·40	
Solid matter .	45·00	100·00	31·60	100·00
Organic matter .	42·12	93·64	23·26	73·61
Fixed salts . .	2·88	6·4	8·34	26·39
Chloride of sodium .	0		4·56	14.43

The decrease of the fixed salts generally, during the stage of hepatisation is remarkable. The last analysis of the urine, when the patient was well, shows the healthy proportion. In vol. xxxv of the *Medico-Chirurgical Transactions* will be found several other cases showing similar results. In some of the cases, it was shown that, although there was not a trace of chloride in the urine, and the blood contained less than its normal proportion, the sputa were very rich in chloride of sodium. In one case, it amounted to upwards of 18 grains in 100 of the solid matter of the sputum. In a fatal case, much chloride was found in the products effused into the air-cells of the lung. In most exudations, and in growing tissues, there is a considerable amount of chloride of sodium. In acute inflammations generally, the proportion of chloride in the urine gradually diminishes until the disease is at its height. When resolution occurs, the chloride reappears, and gradually increases as convalescence advances, until it attains its normal standard. The amount of chloride in the urine is much influenced by the nature of the food, and by the quantity of fluid taken, as remarked when considering the chloride in healthy urine; but the results above described cannot be explained in this manner; for, although patients take less food when they are ill, and therefore less salt, the same results are observed if salt be given to them. Moreover, the disappearance is gradual, and the reappearance is marked by a change in the symptoms of the disease, although the food has remained the same during the whole period of the illness. I have expressed the opinion that, in all probability, the chloride is attracted from the blood in undue proportion to the point where the inflam-

matory changes are taking place; and that, instead of passing through the organism as it does in health, it accumulates at this point until a certain stage of the morbid process is passed, when it is reabsorbed into the blood, and excreted by the ordinary channel. The precise office which the salt plays in these processes is not understood; but certainly, in all the specimens of inflammatory lymph that I have examined, I have always found common salt present in large quantity. In many cases of bronchitis, acute rheumatism, pleurisy, in some cases of skin-disease, and in some other instances in which its absence would appear to be merely an accidental circumstance, no salt can be detected in the urine. We cannot, therefore, regard this diminished proportion or absence of chloride in the urine as a point of any value in the diagnosis of pneumonia, although it must be looked upon as a fact of great interest with reference to the morbid changes which are taking place at the time. The conclusions to which I arrived, after examining the urine, blood, sputum, and inflammatory products, in several cases of pneumonia, are as follows:

1. That in pneumonia there is a total absence of chloride of sodium from the urine at or about the period of hepatisation of the lung.

2. That, soon after resolution of the inflammation, the chloride is again present in the urine, and often in considerable quantity.

3. That, at this period (resolution), the serum of the blood is found to contain a greater amount of chloride than in health.

4. That the presence of chloride of sodium in the urine may be taken as evidence of the existence of a greater quantity of the salt in the blood than is required for the wants of the system generally, or, at least, of an amount sufficient for that purpose; and that the absence of the salt from the urine indicates that the circulating fluid contains less than the normal quantity.

5. That the sputa in pneumonia contain a greater quantity of fixed chloride than healthy pulmonary mucus, if there be not much less than a normal amount in the blood, although there be a complete absence of the salt from the urine. In all cases, however, there is found in the sputa a quantity many times greater than exists in an equal amount of blood at the same period of the disease. The absolute amount present is subject to variation at different periods of the disease, and in different cases.

6. That, in one case which was fatal, the proportion of chloride present in the sputum underwent a decrease, while the amount of solid matter, and especially the extractive matters, increased in quantity. At the same time, the sputum became acid; and in the matters expectorated within the last few hours of the patient's life, a large quantity of grape-sugar was found; but, in that obtained on the day previous to his death, none could be detected.

7. The absence of chloride of sodium from the urine during the stage of hepatisation seems to depend upon a determination of this salt to the inflamed lung; and, when resolution occurs, this force of attraction ceases, and whatever salt has been retained in the lung is reabsorbed, and appears in the urine as usual.

Analysis 18 represents the composition of the urine in an extreme case of *elephantiasis Græcorum*, occurring in a boy about twelve years of age, who was in the hospital some years ago, under Dr. Todd. The emaciation was extreme, and there were a great number of large ulcerated tubercles all over the body, which discharged freely. The absence of the chloride may perhaps be accounted for by the presence of exudation and cell development at the bases of these numerous ulcers. The urine was acid; specific gravity 1020.

Analysis 18.

Water . . .	960·0	
Solid matter . .	40·0	100·00
Fixed salts . .	4·51	11·27

The ash consisted of sulphates and phosphates, with a mere *trace of chloride.*

Analysis 19.

Another specimen about two months after the last. Specific gravity, 1014; acid.

Water . . .	965·1	
Solid matter . .	34·9	100·00
Urea . . .	13·97	40·02
Extractives . .	16·06	46·01
Uric acid . . .	·31	·88
Alkaline salts . .	4·07	11·66
Earthy salts . .	·49	1·40
Sulphuric acid . .	·422	1·20
Phosphoric acid . .	1·389	3·98
Chloride of sodium . .	*not a trace.*	

It is difficult to account for the absence of the chloride in the following analysis. The urine was obtained from a woman aged 31, suffering from hysterical coma. About eleven ounces were drawn off by a catheter. The patient was quiet; skin cool; tongue covered with a thick white fur; pulse 135; respiration 18; sensation very much impaired. The patient did not notice a very severe pinch with the nails.

Analysis 20.

Water	921·41	
Solid matter . . .	78·59	100·00
Uric acid . . .	·57	·72
Urea extractives, etc.	67·70	86·15
Fixed salts . .	10·32	13·13

The salts contained sulphates and phosphates, but *not a trace of chloride* was present.

Sulphates. I have already observed that the proportion of sulphates usually varies according to the urea; and it follows that, in diseases characterised by a considerable disintegration of muscular tissue, we shall find an unusual amount of sulphate in the urine. In *chorea*, the increase of the sulphate and urea

is often very considerable; but there are conditions in which the increase of the sulphates does not appear to be associated with the formation of urea to a correspondingly large amount. An increase in the quantity of sulphate in the urine, in cases of *rheumatic* fever, is noticed in some of Dr. Bence Jones's analyses. In one case, on the fifth day, the urine had a specific gravity of 1026, and yielded 11·89 grains of sulphate of baryta. Dr. Parkes has shown, by some very careful experiments on four cases, that in rheumatic fever the sulphuric acid is greatly increased. In one case, 52½ grains of sulphuric acid and 5½ grains of unoxidised sulphur were excreted in twenty-four hours. The urea was not increased in the same degree. This increase of sulphate is not observed in typhoid fever and scarlatina. It *does not*, therefore, depend merely on increase of temperature. Dr. Parkes suggests that in the blood, in acute rheumatism, there may exist a material richer in sulphur than albumen. Potash increases the tendency of this substance to disintegrate; and hence, whenever liquor potassæ is given, the proportion of sulphates in the urine is augmented.

Urinary constituents.	Condition in rheumatic fever.	Effect produced by liquor potassæ in large doses.
Solids	Increased	Still more increased
Water	Greatly diminished	Slightly increased
Uric acid	Increased	Slightly increased
Sulphur	In considerable quantity	Probably increased
Chlorine	Diminished	Unaffected
Sulphuric acid	Greatly increased	Still more increased*

In many cases of skin-disease, I have found the relative proportion of the sulphates to be considerably augmented. This is well illustrated in Analysis 5, which gives the composition of the urine of a boy suffering from eczema.

* The influence of liquor potassæ on the urine in rheumatic fever. (*Med.-Chir. Review*, vol. xiii, page 248.)

Alkaline Phosphates. Much has already been said upon the quantity and origin of the alkaline phosphate in the urine; and I have brought forward evidence to show that the greater part of the phosphoric acid eliminated, is carried into the organism in the food. A certain proportion, however, there can be little doubt, is formed in the body by the oxidation of the phosphorus of albuminous textures (nervous tissue). In diseases generally, the alterations which have been observed in the quantity of phosphate removed in the urine is to be attributed, to some extent, to the altered diet of the patient. It is reasonable to suppose that, in some conditions of the system in which a more than usual disintegration of tissues rich in phosphorus takes place, more phosphoric acid is formed in the organism than in health. This excess should be found in the urine in the form of alkaline phosphate, and the amount ought to correspond to the activity of the changes taking place. By ascertaining the proportion, we should be able to form an estimate of the quantity of phosphorus oxidised, and therefore of the nerve-tissue disintegrated, of which it was a component part. The really difficult part of the inquiry is to ascertain how much of the total proportion of phosphate present is derived from the food, and how much is actually formed in the organism. The sulphuric acid is almost entirely produced in the body; and there is not, therefore, the same difficulty in estimating the amount of sulphur oxidised, as there is in the case of the phosphorus.

Of late, the importance of this subject has been much increased by attempts to advance the experimental results already obtained in favour of the hypothesis, that the amount of phosphate excreted in the urine is to be regarded as an index of the activity of the nervous system. Those who labour to prove that all the changes in the body are the direct result of certain chemical decompositions, have not hesitated to bring forward these results in favour of their theory. It seems by some to have been regarded as a settled point, that

the quantity of phosphate in the urine varies according to the amount of nervous tissue disintegrated; and it has been assumed that the quantity of work done by the brain is in direct proportion to the activity of the chemical changes going on in the nervous tissue. This question is obviously a most important one, and much more is involved in it than at first appears. I propose, therefore, to lay before you a few of the facts which have been ascertained; and I think we shall find that, in this matter, speculation has to some extent taken the place of reasoning founded upon facts and experimental observations.

Dr. Bence Jones, as is well known, has written several important papers upon this subject. The general conclusions to which he has arrived are the following:—

"In delirium tremens, and in other delirium, a remarkable increase in the amount of sulphates in the urine was frequently observed; and the total phosphates were in the same cases occasionally remarkably diminished.

"In acute inflammatory diseases of the nervous structures, during the most febrile symptoms, an increase was observed in the amount of sulphates in the urine; and the total amount of earthy and alkaline phosphates in these diseases appeared to be increased in the same proportion as the sulphates were increased." (*Phil. Trans.*, 1850, p. 66.)

"In fractures of the skull, the phosphatic salts increase only when any inflammatory action occurs in the brain; and in acute phrenitis, an excessive increase takes place. In delirium tremens, there is a marked deficiency of phosphates, unless they are introduced with the ingesta; an excess is, however, met with in some functional affections of the brain."

These conclusions are founded upon analyses of 1000 grains of urine, in eleven cases of delirium tremens and eight cases of acute inflammatory affections of the nervous centres. From these I select a few of the extremes.

Delirium Tremens and other forms of Delirium.

Case.	Sulphate of baryta per 1000 grains of urine.	Specific gravity.	Total phosphates.
8. Delirium tremens—thirteenth day . . .	13·10	1037·4	9·83
10. Poisoned by laudanum; delirium and excitement—second day . .	7·83	1026·8	7·53
4. Delirium tremens—tenth day	17·31	1024·74	0·87
11. Delirium with phthisis—fourth night . .	6·97	1024·2	0·72

Inflammatory diseases of Nervous Structures, with Head Symptoms.

2. Inflammation of the brain—twelfth day .	3·96	1018·7	5·14
Ditto—thirteenth day .	11·23	1027·26	11·13
6. Inflammation of lungs, with tubercles and violent head symptoms—fourth day . . .	8·55	1027·85	7·19
Ditto—sixth day .	7·81	1026·1	6·43

The quantity of urine passed by the patients in twenty-four hours is not stated, nor is the amount of solid matter in 1000 grains of urine given. It is therefore very difficult from the above data to form an estimate of the total quantity of phosphate removed from the organism in twenty-four hours. Although many of the results, as far as they go, favour the above view, and especially when the numbers are considered with reference to the amount of solid matter estimated from the specific gravity, the increase of the phosphates, in cases of inflammation of nervous structures, cannot, I think, be regarded as established by these observations.

I have estimated the quantity of phosphate in urine in various cases of disease. Some time since, I examined the prine of many patients in St. Luke's Hospital, for Dr. Sutherland, with the view of ascertaining the proportion of alkaline phosphate excreted in different cases of mania, dementia, paralysis of the insane, etc. (*Med.-Chir. Trans.*, vol. xxxviii, p. 261.)

Forty-two analyses were made, and the following formula was filled up in each case.

Water................................
Solid matter..........................
Organic matter......................
Saline matter ....
Phosphate precipitated by chloride of calcium and ammonia..............

Some interesting facts were made out, and the quantity of phosphates relatively to other constituents of the ash differed much from the healthy standard. Some of the results confirmed, as far as they went, Dr. Bence Jones's conclusions; but I do not think we can form a very positive conclusion from these data, seeing that, in some of the cases, the solid matter contained 10 or 12 per cent. of mixed phosphate; while in others only 3 or 4 per cent. was found; and this variation did not always correspond to a difference in the symptoms. I subjoin a few of the most interesting results from two of the series of cases.

Paralysis of the Insane.

21. From a man, aged 36. First attack. It lasted two months. Complete recovery.

22. From a man, aged 45. First attack, of one month's duration. Not relieved.

23. From a man, aged 42. The specimen was taken on a day when he was very violent and noisy.

24. From the same, about three weeks afterwards, when the excitement had passed off.

Analyses.

	21		22	
Reaction	Acid.		Feebly alkaline.	
Specific gravity	1030		1015	
Water	912·6		959·4	
Solid matter	87·4	100·00	40·6	100·00
Fixed salts	21·42	24·50	13·31	32·7
Phosphate of lime precipitated by chloride of calcium and ammonia	5·18	5·92	1·57	3·86

	23		24	
Reaction . . .	Neutral.		Acid.	
Specific gravity . .	1008		1016	
Water . . .	988·6		958·2	
Solid matter . .	11·4	100·00	41·8	100·00
Fixed salts . .	4·74	41·57	8·45	20·21
Phosphate of lime precipitated by chloride of calcium and ammonia . .	2·90	25·44	2·86	6·84

It is important to observe that, in 23 and 24, 1000 grains of urine contained almost exactly the same quantity of phosphates, but that the proportion to the other constituents was very different; the solid matter in the first case containing the very large proportion of 25·44 per cent.; in the second, only 6·84 per cent.

Acute Mania, with Paroxysms.

25. From a man, aged 18, with meningitis. The present is the first attack, and has lasted three months. He recovered.

26. From a woman, aged 55. First attack, which has lasted about three months. She recovered.

27. From a man, aged 26. First attack, which has lasted six days. There was much exhaustion and emaciation. Weighs 7 st. 12 lb. Discharged uncured.

28. From a girl, aged 18. Second attack. Weighs only 6 st. 6 lb.

Analyses.

	25		26	
Reaction . .	Acid.		Feebly acid.	
Specific gravity . .	1020		1023	
Water . . .	945·8		943·00	
Solid matter . .	54·2	100·00	57·60	
Fixed salts . .	12·01	23·81	15·10	26·49
Phosphate of lime precipitated by chloride of calcium and ammonia . .	6·05	11·16	7·14	12·52

	27		28	
Reaction . .	Acid.		Acid.	
Specific gravity . .	1033		1028	
Water . . .	908·00		931·6	
Solid matter . .	92·00		68·4	
Fixed salts . .	13·18	14·32	20·33	29·72
Phosphate of lime precipitated by chloride of calcium and ammonia . .	9·73	10·57	4·49	6·56

It is much to be hoped that such observations will be further carried out by those who have the opportunity. Most valuable results would certainly be obtained, if the urine could be carefully collected for the twenty-four hours.

The conclusions at which Dr. Sutherland arrives, in his paper above referred to, are the following:—

1. A plus quantity of phosphates exists in the urine in the paroxysms of acute mania.

2. A minus quantity exists in the stage of exhaustion in mania, in acute dementia, and in the third stage of paralysis of the insane.

3. The plus and minus quantities of phosphates in the urine correspond with the quantitative analysis of the brain and of the blood; for a plus quantity of phosphorus is found in the brain, and a slight excess of albumen in the blood of maniacal patients; and a minus quantity of phosphorus and albumen are found in the brains of idiots, and a minus quantity of albumen in paralysis of the insane.

4. The plus quantity of phosphates in the urine of cases of acute mania denotes the expenditure of nervous force, and is not a proof of the existence of acute inflammation in this disease.

I have selected the following analyses from my notebook:—

Chronic Inflammation of the Brain.

Analysis 29 shows the proportion of phosphates in the urine of a man, aged 34, who had been suffering from a tumour pressing on the veins of Galen, causing dropsy of the ventricles of the brain. There were many symptoms of chronic inflammation. Specific gravity 1018, acid.

30. Three weeks after the first analysis, acid, clear, pale; specific gravity 1015.

31. After another interval of three weeks, clear, natural colour; specific gravity 1016.

Analyses.

	29		30	31	
Water	962·10		1000·00	956·3	
Solid matter	37·90	100·00		43·70	100·00
Organic matter	27·09	74·12		33·72	77·17
Fixed salts	9·81	25·88		9·98	22·83
Phosphate of lime precipitated by chloride of calcium and ammonia	2·74	7·22	3·53	3·92	8·97

Urine in Epilepsy.

32. From a man suffering from epileptic fits, occurring every five or ten minutes, for seventeen hours. He breathed sterterously the whole time, and no urine could be obtained during this period. Urine was obtained on the next day (June 10th), acid, specific gravity 1024. Contained an abundant deposit of urates.

33. From the same patient, on the 12th; acid, 1024. Contains a good deal of pus.

34. From the same patient, on the 19th; alkaline, 1017.

35. From a very intemperate patient, aged 59, who had epileptic fits every few minutes for thirty hours, followed by exhaustion (twelve hours) and death. There was complete loss of consciousness.

36. From a man, aged 53, suffering from slight general

paralysis, with impaired speech (slight), intellect, and memory Duration of illness, three years. Urine pale, clear; no albumen; feebly acid; specific gravity 1009.

Analyses.

	32		33	
Water . . .	931·2		927·2	
Solid matter . .	68·80	100·00	72·80	100·00
Organic matter .	58·35	86·27	51·01	85·18
Fixed salts . .	9·45	13·73	10·79	14·82
Phosphate precipitated by chloride of calcium and ammonia	6.90	10·11	3·92	5.38

	34		35	36	
Water . .	958·8		1000	976·7	
Solid matter . .	41·20	100·00		23·30	100·00
Organic matter .	34·68	84·18		17·46	75·94
Fixed salts .	6·52	15·82		5·84	25·06
Phosphate precipitated by chloride of calcium and ammonia . .	2·15	5·21	8·86	1·79	7.68

The quantity of phosphate in the first analysis is very great, especially when the small proportion of saline matter in the urine is taken into consideration. In Analysis 32, the ash consists of as much as 73·63 per cent. of phosphate; in 33, 36·30 per cent.; and in 34, the proportion is further diminished to 32·93 per cent.

Urine in Delirium Tremens and Puerperal Mania.

37. From a man, aged 36, on the fifth day of a slight attack of delirium tremens. He had had three severe attacks previously. Clear, high coloured; specific gravity 1015. The saline matter contained much sulphate, but not a trace of chloride.

38. From a man, aged 31, with delirium tremens of a fortnight's duration. Acid; specific gravity 1020.

39. From a woman with puerperal mania. Acid; specific gravity 1012.

Analyses.

	37		38	39
Water . .	959·32		1000·00	1000·00
Solid matter . .	40·68	100·00		
Organic matter .				
Fixed salts . .	6·30	15·48		
Phosphate precipitated by chloride of calcium and ammonia . .	2·93	7·20	7·66	3·40

Urine in Health.

The following analyses show the varying quantity of the phosphates in the urine of a healthy man, twenty-three years of age. The large proportion of fixed salts depended upon the presence of much chloride of sodium.

40. Passed at 2½ P.M., immediately after dinner. Clear, natural colour; acid; specific gravity 1015.

41. Passed at 6 P.M. on the same day, after three hours reading. Acid; specific gravity 1011.

42. Passed at 2 P.M., immediately before dinner, on another day. Feebly acid; specific gravity 1022.

43. Passed at 6½ P.M., four hours after dinner. Acid; specific gravity 1026.

Analyses.

	40		41	
Water	963·60		972·4	
Solid matter . . .	36·40	100.00	27·6	100·00
Organic matter . .	14·75	68·00	19·89	72·07
Fixed salts . . .	11·65	32·00	7·71	27·93
Phosphate of lime precipitated by chloride of calcium and ammonia . .	2·62	7·19	1·92	6·95

	42		43	
Water	943.80		936.80	
Solid matter . . .	56.20	100·00	63·20	100·00
Organic matter . .	37·80	67·26	30.38	63·84
Fixed salts . . .	18·40	32·74	22·82	36·16
Phosphate of lime precipitated by chloride of calcium and ammonia . .	2·40	4·27	6·22	9·84

In the above analyses, can any relation be shown to exist between the symptoms of the patient and the proportion of phosphoric acid? In some, there is undoubtedly an indication of such a relation; but in others the proportion of phosphate is as great, although there was no evidence whatever of increased cerebral action or of inflammation. Without discussing the abstract question, I cannot think that the evidence at present obtained is sufficient to enable us to form a general conclusion. The inquiry is more difficult than it at first sight appears to be. Practically, we must determine how much phosphate is derived from the food, and how much from the oxidation of phosphorus. We have then to ascertain the proportion formed in the muscular system, as well as in the nervous structures. Dr. Hammond, who has carried on very many valuable researches upon subjects of this nature, has found that the phosphates in the urine are greatly increased after active exercise.

In any case of disease in which the excretion of an increased quantity of phosphates in the urine is suspected, we should ascertain—

1. The total quantity of phosphoric acid, in combination with alkalies, in the urine passed in the twenty-four hours.

2. The amount taken in the food within the same period of time.

To be more exact, the earthy phosphate in the urine should also be estimated, as well as that which passes off in the fæces.

I have not been able to ascertain that the quantity of phosphate excreted in the urine has ever been compared with the amount taken in the food, in diseases in which we should expect an increased disintegration of nervous tissue. Until experiments have been conducted so as to furnish us with positive data on this point, I do not think we are in a position to determine the question at issue. The results which have as yet been obtained are not sufficiently conclusive, as they fail to show even the total absolute amount of mixed phosphate eliminated from the body in twenty-four hours. One can hardly

suppose that, in cases in which the greatest possible amount of disintegration of nervous tissue was occurring, a very great increase in the phosphate would be observed, considering how very much of the total quantity is derived from the food; and of the comparatively small amount *formed* in the organism, a considerable proportion originates in the muscular tissue. Very exact observations upon the in and out going phosphates have therefore to be made before we can hope to have the fact established conclusively.

I have ventured to occupy much time in the discussion of this question, and have gone more into detail than perhaps its importance, in the opinion of many practical men, demands. Still, when a long train of theories is constructed, the truth of which entirely depends upon the accuracy and correct interpretation of the experimental results from which it starts, it behoves us to examine rigorously into the nature of this foundation; for until the fundamental facts have been firmly established, we cannot allow ourselves to be led by the reasoning, however logical it may be; or receive the conclusions, however closely they may follow on the premises. While, therefore, I do not deny that increased nervous action may be associated with the formation of an increased quantity of phosphoric acid, which is eliminated in the urine, I think that the facts hitherto advanced in favour of this view are by no means conclusive; and I therefore hold that we are not yet in a position to form any theory upon the nature of the changes occurring in health or disease, in cerebral action, regarded from this point of view.

Earthy Phosphates. The proportion of earthy phosphates does not seem to vary much in disease. Dr. Bence Jones has shown that, in cases in which the alkaline phosphates are increased, there is no corresponding increase in the proportion of earthy phosphates. Much of the earthy phosphate eliminated in the urine in health is doubtless derived from the food, but a certain proportion is set free in the disintegration of the tissues, especially the osseous tissues. An increase of earthy phosphate is observed in the urine in some very rare cases of

disease, in which the earthy matter of the bones is absorbed (*mollities ossium*). In one acute case of this disease, Dr. Bence Jones (*Phil. Trans.*, 1848) obtained indistinct evidence of the presence of chlorine, and suggests that in future this substance should be searched for, as it may possibly be directly concerned in the removal of the earthy material from bones. This specimen of urine contained a peculiar substance of an albuminous nature. In 1000 grains, there were 1.20 gr. of earthy phosphate; and the solid matter contained 1·18 per cent. The analysis will be given in Lecture v, under *Albumen*. I have had opportunities of making analyses of the urine in two cases of mollities ossium. They were both well marked and fatal cases of the disease, and the specimens of urine were obtained shortly before death. The patients were quite bedridden, and the bones were so soft as to be readily indented by the finger.

44. This specimen of urine, from a woman suffering from mollities ossium, was sent to me by Dr. Chambers. The deposit contained oxalate of lime, with numerous stellate masses and separate crystals of triple phosphate. Reaction, acid; specific gravity, 1014.

45. From a case sent by Dr. Greenhalgh. Morning specimen.

46. Night specimen.

Analyses.

	44		45		46	
Water	971·9		965·2		960·88	
Solid matter	28·1	100	34·8	100·00	39·12	100·00
Urea	5·0	17·7				
Extractives	10·22	36·3				
Fixed salts	12·88	45·81	14·44	41·49	5·25	13·42
Earthy phosphs. precipitated by ammonia	1·185	4·21	·79	2·27	·4	1·02
Alkaline phosphs. precipitated by sulph. magnesia and ammonia	1·13	4·21	·86	2·47	1·3	3·32
Triple phosphs. filtered from the urine			·058	·16		

The large proportion of earthy phosphate in these analyses is a very interesting fact. In the first, the earthy actually exceeds the alkaline phosphate; and in the second, it is nearly equal to it. In healthy urine, the alkaline phosphate usually amounts to from ten to fifteen times as much as the earthy phosphate. The inorganic salts generally, are in considerable excess.

Excess of Earthy Phosphate, which has been shown so rarely to exist, must be carefully distinguished from the mere deposit of a certain amount in an insoluble form. The earthy phosphates very often form an insoluble deposit in urine. The characters of these salts will be described under *Urinary Deposits*. It is hardly necessary to observe, that the deposit does not depend necessarily upon the excretion of an excessive quantity, but is often due to a change having occurred in some of the constituents which normally hold these salts in solution. A small quantity of deposit of earthy phosphates makes a great show in urine; and it is obvious that a very large proportion might be held in solution in the urine, and thus escape detection, unless an analysis were made. In the case just cited, the greater part of the earthy phosphate was in *solution* in the urine. It is common enough to find the deposit in cases of dyspepsia and overwork, and it is often spoken of as indicating the destruction of nervous matter. In these conditions, the urine often becomes neutral or slightly alkaline, and this causes the precipitation of the phosphate. As before remarked, the quantity of the earthy phosphates is not perceptibly affected by those circumstances which influence the quantity of the alkaline phosphate; and, although an excess of earthy phosphate is of considerable importance, its existence depends upon morbid actions of a different nature. A diet composed of much sugar diminished the earthy phosphate in the urine (Böcker).

Of the principal Points to be ascertained from a Quantitative Analysis of Urine in Disease.

In clinical investigation, the principal points which it is important to ascertain with regard to the characters of the urine are the following:—

Quantity passed in twenty-four hours.

Specific gravity of specimens passed in the morning and evening.

Reaction of specimens in the morning, and about three hours after meals.

Colour; smell; consistence.

Presence or absence of a deposit. If present, its microscopical characters. (Lectures VIII, IX, X.)

Presence of any of the substances to be described in Lecture V—albumen, colouring matter of bile, sugar, etc.

Estimation of the quantity of constituents in 1000 grains of the mixed urine of twenty-four hours. From these data, the quantities passed in twenty-four hours are to be calculated.

	In 1000 grs.	In 24 hrs.
Water	—	—
Solid matter	—	—
Organic matter	—	—
Saline matter	—	—
Urea	—	—
Uric acid	—	—
Free acid	—	—
Extractives, etc.	—	—
Alkaline phosphates, or phosphoric acid	—	—
Earthy phosphates	—	—
Sulphates, or sulphuric acid	—	—
Chloride of sodium, or chlorine	—	—

In particular diseases, it is very desirable to ascertain the quantity of one or two constituents removed in the twenty-four hours; and very much valuable information with regard to the nature of many diseases might be obtained by a number of careful and exact analyses of this kind. It is not necessary to

fill up the above scheme in every case. In some, it would be desirable to know the amount of urea and uric acid with precision; in others, the amount of urea and sulphates. In diseases of the nervous system, the exact amount of alkaline phosphates passed in the twenty-four hours should be noted, etc. Before the investigation is commenced, the observer should determine exactly the points he wishes to ascertain, construct a table, and fill up the several columns daily from his analysis-book. Every analysis should be made in precisely the same manner, and careful notes of the case should be recorded daily. If possible, analyses of the urine should be made after the patient is restored to health; so that the quantities of the various constituents eliminated from the body in a state of health and disease may be accurately compared, and the patient should be weighed at intervals while under observation.

LECTURE V.

URINE IN DISEASE. SOLUBLE SUBSTANCES PRESENT IN URINE IN DISEASE WHICH DO NOT EXIST IN THE HEALTHY SECRETION. ALBUMEN. *Of Detecting the Presence of Albumen; Tests; Nitric Acid; Heat; Anomalous Results in Employing these Tests; Apparent Presence of Albumen in Urine which contains none; Phosphate resembling Albumen; Uric Acid resembling Albumen; Cases. Apparent Absence of Albumen in Urine which contains a large Quantity; Cases. Cause of the Precipitation of Albumen by Heat being prevented by a Trace of Nitric Acid. Other Tests for Albumen. On Estimating the Quantity of Albumen. Peculiar Substance in Urine allied to Albumen. Of the Importance of Albumen in Urine in a Clinical point of view. Dropsy in Disease of the Kidney.* BILE. *Tests. Nitric Acid. Heller's Test. Pettenkofer's Test. Yellow Colour of the Cells, etc., in the Urinary Deposit.* SUGAR. *General Characters of the Urine in Diabetes. Diabetic Sugar. Tests for Diabetic Sugar; Moore's Test; Trommer's Test; Barreswill's and other Solutions. On Testing for Sugar when only Traces are present. Circumstances interfering with the Action of Trommer's Test. Of the Yeast Test. Maumené's or the Perchloride of Tin Test. Bismuth Test. Of Estimating the Quantity of Sugar; volumetrically; by Fermentation; by Dr. Garrod's Method; by the Polarising Saccharimeter. Circumstances under which Sugar is excreted in the Urine. Analyses of Urine in Diabetes.* OTHER SOLUBLE SUBSTANCES WHICH ARE NOT PRESENT IN HEALTH. LEUCINE. TYROSINE. INOSITE. ACETONE. CYSTINE.

GENTLEMEN,—We will now pass on to the consideration of certain soluble substances not found in healthy urine, the presence of which is to be ascertained by the application of *chemical tests*. In many cases, however, our first suspicion of the existence of one of these bodies is excited by certain peculiar characters affecting the deposit or the colour of the urine, or by its

peculiar smell or unusually high specific gravity. The substances referred to, being perfectly soluble in the fluid, cannot be detected by microscopical examination; but, in many instances, we infer their presence from the microscopical characters of certain bodies in the deposit. Thus, the detection of epithelial cells of a yellowish colour would lead us to test the urine for *biliary colouring matter;* if casts were found upon microscopical examination of the deposit, we should test for *albumen;* if torulæ were present, we should suspect the presence of *sugar.* In all cases, our conclusions must be verified by the application of appropriate tests, which we shall presently consider.

The most important soluble substances present in the urine in disease, but absent in the healthy secretion, are, *albumen*, *biliary constituents*, and *sugar*. The clinical importance of these is so great, that they deserve your special attention.

Albumen.

The occurrence of albumen in the urine has been regarded as a most important pathological fact ever since the connexion between dropsy and disease of the kidneys was established by Dr. Bright. Albumen, it need scarcely be said, is absent from the urine of healthy persons, although now and then it may be detected for a short period of time in the urine of individuals who are not suffering from any serious or permanent derangement of the health. The presence of albumen must always be regarded by the physician as a point of serious importance, although at the same time, *per se*, it cannot be taken as evidence of the existence of any organic lesion, unless it has been clearly detected from day to day for a certain time. Many of the causes which give rise to the escape of serum from the vessels in other parts of the body, independent of disease, will determine its transudation through the walls of the renal

capillaries, and, as a matter of course, it will be found in the urine.

To recognise with certainty the presence of a substance in the urine having so important a bearing in the discovery and interpretation of certain morbid processes, as albumen, is obviously a point of the utmost importance to the practitioner. In the examination of the urine of patients, simple tests are at once applied, in order to determine if this substance be present or absent. In the majority of cases, such information is easily obtained; but occasionally an instance occurs in which, without great care, an erroneous conclusion is likely to be arrived at after the ordinary tests have been applied. As this question is one of very great practical importance, and of much interest, I propose to consider it at somewhat greater length than is usual in works devoted to the clinical examination of urine. The reactions to which I shall refer are not imaginary, but have actually occurred; and I have known instances in which albumen was stated to be absent when the urine contained a large quantity; and other specimens have fallen under my notice, which, although they really contained none, yielded a precipitate having many of the characters of albumen. Let us then investigate the phenomena *seriatim.*

Tests for Albumen in Urine.

1. *Albumen is usually precipitated from its solution upon the addition of a few drops of nitric acid.* Heller recommended that the acid should be allowed to flow to the bottom of the tube containing the urine. In this manner, three strata are formed, the lowest stratum consisting of the pure acid, above which is the precipitated albumen, while the upper stratum consists of the fluid containing the albumen uncoagulated.

2. *Albumen is also generally coagulated by the application of heat* (140° to 167° Fahr.). If very dilute, a higher temperature is required. The best way of testing urine by heat is the

following :—An ordinary test-tube is about half filled with the urine, and is to be held by the lower part. Heat is applied to a point near the *surface* of the fluid; the tube being shaken a little at the time, to prevent the glass being cracked. The slightest precipitate cannot fail to be observed, as the fluid below remains perfectly unchanged. When urates are present, this plan is very useful, as we get three distinct strata; the upper one formed of coagulated albumen ; the next clear, in consequence of the solution of the urates at a temperature somewhat below that necessary for the coagulation of the albumen; and lastly, the unchanged urates.

3. *If the solution of albumen be alkaline, no precipitate will be produced by heat. We are, therefore, generally directed to neutralise the alkali by an acid before heat is applied.* If excess of acid be added, the albumen is, of course, precipitated in the insoluble form, without the application of heat.

Frequently specimens of urine are met with which exhibit one or more of the following peculiarities, which tend either to make us believe that albumen is present when it is not, or cause us to conclude that it is absent when the urine contains it.

1. Upon the application of heat, the specimen may become turbid, in consequence of the precipitation of phosphate. The reaction of the urine in this case would generally be neutral or feebly alkaline; but sometimes urine depositing phosphate on the application of heat is of a decidedly acid reaction (Lecture III).

2. Upon the addition of nitric acid, the specimen becomes turbid, in consequence of the decomposition of the urates held in solution in the urine, and the deposition of uric acid in a granular state. If the acidified urine be boiled, it usually becomes clear with the development of a pinkish or brown colour, consequent upon the decomposition of the uric acid.

3. Upon adding nitric acid to some specimens of urine of high specific gravity, an abundant precipitate of a crystalline

character is produced. This consists of nitrate of urea, and is easily recognised by its crystalline character. It seldom appears immediately, and is hardly likely to be mistaken for albumen, except by a most superficial observer.

4. After adding a drop or two of nitric acid to urine suspected to contain albumen, in order to render it distinctly acid, *no precipitate is produced upon boiling, although a large quantity of albumen may be present.* This is constant in all specimens of albuminous urine, and shows the importance of never boiling urine suspected to contain albumen in a tube which may contain, by accident, a drop or two of nitric acid.

5. Cubebs, copaiba, and some other resinous substances, taken internally, are said to give rise to precipitates in the urine which are liable to be mistaken for albumen.

A Precipitate produced in Urine containing no Albumen.

Phosphate resembling Albumen. The precipitate of phosphates is very readily distinguished from albumen by its solubility in a little acid. Upon the addition of a few drops of nitric acid, the turbidity instantly disappears, and the solution becomes perfectly clear.

Uric Acid resembling Albumen. When a precipitate of uric acid in a minute state of division is caused in consequence of the decomposition of the urates by nitric acid, its nature may be ascertained by allowing the mixture to stand for some time, when the minute granules gradually increase in size, and at length become crystals, the nature of which is at once recognised upon microscopical examination. In some cases, the crystals may be seen to form under the microscope. This precipitation of uric acid on adding nitric acid often leads to mistakes, and albumen is stated to be present in urine which really does not contain a trace. Several cases of this precipitate have occurred to myself, and I have heard of many others in the practice of friends. It has hap-

pened in the wards of our hospital, that the precipitate produced by nitric acid has been inferred by the clinical clerk to consist of albumen, when subsequently no precipitate could be obtained. The fallacy was explained by careful examination afterwards.

Dr. G. O. Rees has met with urine affording this precipitate of uric acid on the addition of nitric acid in cases of typhoid fever. Most of the instances which I have met with occurred in cases of liver-affection. I extract two or three, as examples.

Urine from a Patient suffering from large Hydatid Tumours of the Liver. A small quantity of the urine was filtered, and, upon the addition of a little nitric acid, a precipitate was produced. After standing a little while, this was examined by the microscope, and found to consist of minute crystals of uric acid. These were dissolved upon the application of heat; but, as the solution cooled, they were deposited again in the form of much larger crystals.

A specimen of urine exhibiting the same peculiarity contained excess of urea. Upon the addition of half its bulk of nitric acid, the mixture became nearly solid, from the formation of crystals of nitrate of urea. The deposit in this instance consisted partly of urate of soda.

Another example, of which I have kept notes, occurred in a man aged 49, suffering from *rheumatic fever*. The urine was acid, specific gravity 1027, and contained much urate of soda. The practitioner who first saw the case boiled a portion of the urine. It remained clear; and he said, therefore, that it contained no albumen. A physician afterwards tested a portion of the same urine with nitric acid; and, finding that an abundant precipitate was produced, affirmed that much albumen was present. The deposit produced by nitric acid was found, by subsequent examination, to be dissolved by heat; and, when a portion was examined in the microscope, its true nature was decided by the presence of numerous uric acid crystals.

No Precipitate produced in Urine containing Albumen.

Albumen not coagulated by heat when a little nitric acid is present. Upon the careful addition of a drop of nitric acid, the precipitate at first formed when the acid comes in contact with the urine, slowly dissolves as it descends towards the bottom. Upon boiling this *acidified solution, no precipitate of albumen will take place.* Upon the further addition, however, of nitric acid, the albumen is precipitated.

This reaction has often led to mistakes. Not unfrequently albuminous urine has been poured into a test-tube which contained a trace of the nitric acid remaining from some previous experiment; and, upon boiling the mixture under these circumstances, no precipitate of albumen has occurred. If a few drops of a dilute solution of nitric acid be added to a portion of albuminous urine in a test-tube, and the mixture boiled, no precipitate will take place. In fact, the addition of a little dilute nitric acid will prevent the coagulation of albumen by heat. Dr. Bence Jones was, I believe, the first to explain this fact, in a communication to the editor of the *Medical Gazette* (vol. xxvii, p. 289); and, so far as I can ascertain, no other explanation for the circumstance than that offered by him has been given. Dr. Jones thinks that the solution of the albumen is owing to the formation of a nitrate of albumen which is soluble in a weak solution of nitric acid, even though boiling, but insoluble in a mixture of acid of moderate strength. Dr. Bence Jones has also shown that albumen is not always precipitated from very acid urine upon the application of heat. From observations I have made, however, I have been led to conclude that the above result depends rather upon the decomposition of the phosphates by the nitric acid, and the consequent development of free phosphoric acid in which acid albumen is freely soluble. This view has been confirmed by some experiments which I made some time since on the subject, and which have since been many times repeated. A

weak solution of albumen was treated with a few drops of chloride of calcium, and afterwards with a little ammonia. After having stood for twenty-four hours, it was filtered. In this manner, any soluble phosphates present were removed. The solution was then tested as follows:—

1. Albumen was precipitated by the application of heat, or by the addition of nitric acid, as usually occurs.

2. A very small quantity of dilute nitric acid did not prevent the coagulation of the albumen by heat.

3. After the addition of a few drops of phosphoric acid, the fluid no longer coagulated upon being boiled.

Some of the same solution as the above, which had not been treated with chloride of calcium and ammonia, afforded the same results upon the application of the tests as other albuminous solutions. A few drops of a weak solution of nitric acid, or a little phosphoric acid, prevented the precipitation of the albumen by heat. The addition of phosphoric acid to an albuminous solution, or a soluble phosphate and a little nitric acid, prevented the precipitation of the albumen by heat.

These results, therefore, led me to conclude that a trace of nitric acid prevents the coagulation of a moderately strong solution of albumen by heat, in consequence of decomposing the phosphates and setting free phosphoric acid, in which the albumen is soluble. When, however, excess of nitric acid is added, its action predominates over that of the phosphoric acid, and the albumen is precipitated.

At the same time, it must be admitted that there are several facts connected with the behaviour of weak solutions of albumen with acid, and under the influence of heat, which are not satisfactorily explained; and forms of albumen having different reactions are from time to time met with. The whole subject requires further careful investigation.

Scherer describes a variety of albumen which is only imperfectly coagulated by heat. It is probable, however, that many

of the peculiar reactions met with from time to time depend upon the presence of other substances dissolved with the albumen, rather than upon any peculiar properties of the albumen itself, or the existence of a variety of this substance.

Other Tests for Albumen. Albumen is precipitated from its solutions by alcohol, alum, and many metallic salts, as those of lead, mercury, copper, and silver. Bichloride of mercury is employed as a test, and ferrocyanide of potassium precipitates a solution of albumen to which acetic acid has been added. These salts will, however, produce precipitates in solutions of other substances allied to albumen.

On Estimating the Quantity of Albumen in Urine. The quantity of albumen varies much in different cases, sometimes amounting to a mere trace; while, in other instances, a proportion not much inferior to that present in serum has been met with. In order to estimate the quantity of albumen, it is only necessary to add acetic acid, and heat the urine in a water-bath to a temperature of 194°, or until it boils. The precipitate is to be collected on a weighed filter, well washed, dried, and weighed. The albumen always contains a small quantity of earthy salts, which are obtained by incineration. The residue must be deducted from the weight of the dried precipitate.

Albuminous Urine, from a patient with acute inflammation of the kidney. The deposit contained numerous granular casts, but no fat-cells were present; specific gravity, 1015; acid. The albumen coagulated by heat and nitric acid.

Analysis 46.

		In 100 parts of solids.
Water	952·00	
Solid matter . . .	48·00	100·00
Urea	13·052	27·19
Albumen, mucus, and uric acid	19·204	40·00
Extractives . . .	12·864	26·80
Alkaline salts . . .	2·784	5·80
Earthy salts . . .	·096	·20

New Substance allied to Albumen. Dr. Bence Jones obtained a new substance allied to albumen from the urine of a patient (under the care of Dr. Watson and Dr. MacIntyre) suffering from mollities ossium. The urine was slightly acid; specific gravity, 1034.2 (*Phil. Trans.* for 1848, p. 55). The deposit consisted of phosphate of lime, oxalate of lime, and cylinders of fibrine. Phosphates were precipitated by heat; but the urine was cleared by adding a drop of acid. No precipitate was produced by nitric acid; but, after being heated and left to cool, it became solid. The solid material was redissolved by heat, and precipitated again when the mixture became cool. On some days, the urine coagulated by boiling; on others, prolonged boiling produced no change. A specimen, which did not coagulate by boiling, was carefully examined. It was acid; specific gravity, 1039.6. It contained much urate of ammonia, phosphate of lime, and oxalate of lime. The urine contained—

		In 100 parts of solids.
Water	890·72	
Solid matter	109·28	100·00
New substance	66·97	61·28
Urea	29·90	27·36
Uric acid	·96	·87
Earthy phosphate	1·20	1·18
Chloride of sodium	3·83	3·50
Sulphate of potash	2·10	1·92
Alkaline phosphate	4·45	4·07

The new substance was precipitated from the urine by alcohol, well washed, and ultimate analyses were made. It contained 1·00 per cent. of sulphur, and ·20 per cent. of phosphorus. This substance is the *hydrated deutoxide of albumen.* It was soluble in boiling water, and the precipitate produced by nitric acid was redissolved by heat, and it formed again as the mixture cooled. A similar substance occurs in small quantity in pus, and in the secretion from the vesiculæ seminales. The urine contained 66·97 parts per 1000 of this substance—an amount equal to the quantity of albumen in the

blood. The patient was passing about thirty-five ounces of urine daily, which would contain upwards of 1000 grains, or more than two ounces of this new material.

Dr. Bence Jones recommends that this substance should be looked for again in acute cases of mollities ossium. He suggests that the reddening of the urine upon the addition of nitric acid might lead to its detection.

Of the importance of Albumen in the Urine in a clinical point of view. In the majority of cases, in which the urine contains a very large quantity of albumen, and especially if the urine be of specific gravity of 1020 or higher, the inference will be that the case is an acute one, and that this large quantity of albumen has not been passing from the kidney for any length of time. By far the majority of these acute cases recover if the patients are placed under favourable circumstances. In some instances, however, the circulation through the kidney becomes more and more obstructed; the urinary constituents accumulate in the blood and seriously impair the various actions going on in the body, and especially affect the nervous system; and death results, probably preceded by coma and sometimes by convulsions. Occasionally pus is found in considerable quantity in the uriniferous tubes. Sometimes the acute stage passes off, and the albumen, although it diminishes in quantity, does not entirely disappear from the urine, and the acute attack afterwards proves to have been the commencement of chronic kidney-disease.

If the quantity of albumen be small, amounting merely to milkiness or opalescence when heat is applied, or nitric acid added to the urine, and especially if the urine be pale and of specific gravity 1012 or lower, we should suspect that the lesion giving rise to the escape of the albumen was chronic, and would ultimately destroy life. If the proportion of urea to the other constituents of the solid matter were large, we should form a more favourable opinion than if the percentage in the solid matter were very much less than in health. In the latter case,

a great part of the renal structure would probably be involved; but, in the former, there would be reason to think the disease had only affected a certain number of the secreting tubules. There are, however, some exceptions to these general statements. Patients have passed small quantities of albumen in the urine for many months, and it has afterwards disappeared. In other cases the progress of the disease is exceedingly slow. I have known a man pass urine of the character above mentioned for upwards of twelve years; and I believe that this might go on for twenty years, or even longer, the patient perhaps dying at last of some other malady. Under favourable circumstances, the life of patients suffering from certain forms of chronic kidney-disease may undoubtedly be prolonged for years; but it must always be borne in mind that such persons are more likely to suffer from exhausting influences, cold, fatigue, etc., than others; and an attack which would cause no alarm for the safety of a man previously in good health, might be rapidly fatal to them.

It is very important that the medical officers of Life Insurances should be aware that there are many instances of persons having chronic disease of the kidney, who are not themselves aware of it. Neither is there in many of these cases anything in the appearance or history of the person that would cause the physician to suspect the true nature of the case. The discovery of albumen in the urine, or of casts in the deposit, is sometimes the only point which leads the practitioner to a correct knowledge of the doubtful nature of the life. Now, if one of these persons experienced a severe attack of catarrh, his life might be endangered; and any exposure to cold would be very likely to set up acute inflammation of the kidneys, already impaired by disease, and thus prove fatal. The only way to discover such a condition, is to institute a careful examination of the urine in every case; but, to carry this out practically, it must be confessed there are many difficulties and objections. A microscopic examination of the deposit in the urine will

probably throw much light upon the case, and enable us to diagnose the condition with much greater precision than is possible from a mere chemical examination. We cannot be too cautious in arriving at a prognosis in these cases. Every circumstance connected with the individual case must be carefully considered, and the state of nutrition, the progress the disease has made in a given time, the state of other organs, the constitution of the patient, his circumstances, temperament, etc., must be passed in review. Even with the greatest care, we shall seldom feel justified in expressing any but a very guarded opinion as to the probable duration of life.

Albumen is always found in small quantity in urine containing pus. We shall therefore meet with it in cases of inflammation of the pelvis of the kidney (pyelitis), and in cases of inflammation of the bladder and of the mucous membrane of the urinary organs generally. Whenever blood is present in the urine albumen is detected; for, if blood-corpuscles escape from ruptured capillaries, a certain quantity of serum must at the same time pass through the same apertures. The colouring matter of the blood is sometime passed in urine in a state of solution; but in this case, also, a certain quantity of albumen is present.

Dr. Bence Jones detected albumen in the urine of a patient who passed spermatozoa. The urine passed in the morning contained spermatozoa and albumen. The evening specimen contained neither. On a subsequent examination, no albumen could be detected.

I have detected albumen in many cases of pneumonia during the period of hepatisation of the lungs. It is present, also, in the specimens of urine first passed after the period of suppression in cholera. In some cases of acute rheumatism with pericarditis it is observed; and it has been occasionally detected in continued fever. In puerperal fever it is often met with, and in puerperal convulsions it is almost constantly present. Dr. Lever found that it was absent in only one case out

of fifty. The pressure of the gravid uterus is probably a cause of the albuminous urine met with in some cases of pregnancy, but it cannot always be referred to the same cause, for it occurs at an early period of pregnancy, when the uterus is too small to exert much pressure. Dr. Tyler Smith considers that it is to be accounted for by an influence exerted upon the nerves, in those cases in which it is not connected with organic disease. After intermittent fevers albumen frequently escapes in the urine. In cases in which any physical impediment to the return of blood in the emulgent veins or inferior cava exists, and in some cases of obstructed portal circulation, as in cirrhosis of the liver, traces of albumen may be detected in the urine. In anæmia, and in cases of dropsy depending upon an impoverished state of the blood, albumen is often passed. Sometimes a large quantity of blood extractive matter is also present. After long continued hæmorrhages, when dropsy occurs, we not unfrequently find albumen in the urine. In these cases it does not depend upon kidney-disease, but upon the state of the blood. Just as serum escapes from the capillaries of various tissues of the body, it is prone to transude through the renal vessels. Lastly, in persons who have suffered for many years from affections which produce alterations in the capillary walls, albumen may pass off in the urine; and towards the termination of exhausting diseases it is frequently present.

In those cases in which its presence depends upon obstruction to the circulation in the kidney, the impediment may be *functional or temporary*, or it may be *organic and permanent*. As examples of the presence of albumen depending upon temporary congestion, may be adduced certain cases of pneumonia and cholera, cases of acute dropsy, and of dropsy consequent upon scarlatina, with many others. Fatty degeneration and chronic nephritis may be brought forward as instances of structural disease, which permanently affects the circulation of the blood through the kidney, so as to cause albumen to transude through the capillary vessels.

In the majority of cases, the vessels of the Malpighian tuft doubtless form the precise seat of the escape of albumen; but there are reasons for believing that albumen sometimes passes from the capillaries surrounding the convoluted portion of the uriniferous tubes, and in some instances from those in contact with the straight portion. (*Archives of Medicine*, vol. i, p. 300.)

In most cases in which albumen occurs in the urine, casts of the uriniferous tubes are also found; for with the serum a certain quantity of coagulable material transudes, and this becomes solid while it lies in the tube, of which it thus takes a mould, and entangles in its meshes any loose bodies, as particles of epithelium, etc., which may happen to be in the tube at the time. In the first series of cases alluded to, casts are often absent, or, if formed, they are perfectly transparent. On the other hand, where the structure of the kidney is altered, the casts often afford evidence of the nature of the lesion. We shall consider this part of the subject in the next lecture. Albumen is, however, often present without any deposit, so that for its detection we must rely solely on chemical tests.

Bile.

When much bile is present in urine, it gives to the secretion a very dark yellow colour, which is even more distinct when thin layers are placed upon a perfectly white surface, as on a plate, than where a considerable bulk of urine is examined. This arises from the presence of the colouring matter, which has received the name of *biliverdin*. It may be completely removed from any solution containing bile by causing it to filter through a layer of charcoal. The presence of bile in urine is commonly observed in cases of jaundice. From some cause or other, as from pressure upon, or obstruction of, the common duct, bile is partly or entirely prevented from escaping into the intestine. The gall-bladder and duct soon become distended

by the accumulation of the secreted bile, which, finding no escape, is reabsorbed, no doubt, partly by the veins and partly by the lymphatics. It thus passes into the blood, and is partly deposited in the tissues and partly carried off in the urine. That scarcely any bile passes into the intestine, is proved by the pale colour, offensive odour, and clay-like consistence of the fæces. Cases of jaundice caused by a temporary obstruction in the common duct are very common. The urine is often of a very dark yellow colour, and remains so for two or three weeks or a month, when the bile generally passes into the intestine by its normal channel, and the patient soon recovers. Small and occasional doses of mercury, with dilute acids, expedite the recovery of these cases of simple jaundice. In cases depending upon permanent closure of the duct, as from the pressure of a tumour, impaction of a gall-stone, etc., the jaundice continues, and bile passes off in the urine as long as the liver retains the power of secreting bile. The presence of bile in the urine is due to the kidneys taking upon themselves to a certain extent the office of the liver when the healthy secreting functions of this gland are interfered with.

Several tests have been proposed for the detection of bile in urine. The efficacy of some of these tests depends upon a change being produced in the colouring matter; that of others upon alterations of the resinous acids.

For Detecting the Colouring Matter of the Bile.

1. *The Nitric Acid Test.* This may be applied in two ways.

(*a.*) A few drops of the biliary urine are to be poured upon a white plate, and a drop of nitric acid allowed to fall upon it. As the acid gradually mixes with the surrounding fluid, a play of colours, commencing in green, passing through various shades, and terminating in red, will be observed.

(*b.*) A portion of the urine is to be placed in a test tube,

and treated as before. If much bile be present, a bluish-green colour at first appears. This is succeeded by various shades, until the play of colours terminates in red.

2. *Heller's test* consists in adding to the suspected urine a few drops of a solution of albumen, and, after agitation, a little nitric acid is added. If the colouring matter of bile is present, the flocculi of albumen which are precipitated will possess a dull green or bluish colour.

Not unfrequently, the albuminous flocculi, when thrown down by nitric acid, are more or less coloured in consequence of the action of the nitric acid on the colouring matter of the urine (uroxanthine). The colour is sometimes reddish, sometimes of a bluish colour. This change is not unfrequently observed in albuminous urine; and Dr. Basham considers it a condition of very unfavourable significance, and states that he has met with it most frequently in the acute forms of renal disease (*On Dropsy Connected with Disease of the Kidneys*, p. 48). This reaction must not be mistaken for that dependent upon biliary colouring matter.

3. After exposing urine to the air for a day or two, crystals of triple phosphate are formed, as is well known. If bile pigment be present, these crystals have a yellow tinge (Hassall, *The Urine*, page 27).

The three tests just described enable us to detect only the colouring matter of the bile.

4. In urine containing bile, the precipitate produced by the addition of acetate of lead has a yellowish colour.

For Detecting the Biliary Acids.

5. *Pettenkofer's Test.* If albumen be present, this must be coagulated, and separated by filtration. The urine is to be treated with about two-thirds of its bulk of strong sulphuric acid, which is free from sulphurous acid, adding the acid drop by drop, to prevent the temperature rising much above 100°; a little sugar or a drop or two of syrup may now be added to

the mixture, and in the course of a minute or two a violet tinge will occur if bile be present. This test is not perfectly satisfactory, since it is very easy to obtain a reddish colour by the action of the acid upon the sugar if albumen and no bile is present; moreover, oil of turpentine, oil of lemons, and of cloves, with other substances, yield similar results. In all these cases, however, the colour is not bright like that produced when bile is present. The action of the sulphuric acid on the sugar alone produces a brownish-red, but this cannot be mistaken, as the colour is very different from that developed by bile. I recommend everyone to become familiar with these colours, by going through the experiments for himself by daylight with a diluted solution of bile.

The method of applying this test has been modified by Dr. Felix Hoppe, whose plan answers exceedingly well, and is so delicate that the smallest quantity of biliary acid can be detected with the greatest certainty. The urine suspected to contain bile is to be treated with excess of milk of lime, and boiled for half an hour. The clear fluid obtained by filtration is evaporated nearly to dryness, and then decomposed with excess of strong hydrochloric acid. The mixture is to be kept boiling for half an hour, and the acid is to be removed from time to time, to prevent the spurting which would occur if the mixture became too concentrated. When completely cold, the mixture is to be diluted with from six to eight times its volume of water. The turbid solution is to be thrown on a filter, and the resinous mass washed until the water runs through quite colourless. The insoluble mass is next to be dissolved in spirit containing 90 per cent. of real alcohol, decolorised with animal charcoal, again filtered, and evaporated to dryness over a water-bath. The yellowish resinous residue is pure *choloidic acid*. By warming it, it emits the peculiar musk-like odour. It is to be dissolved in a little caustic soda and warm water, a little sugar added, and three drops of concentrated sulphuric acid are allowed to fall slowly into the mixture. The resinous acid is

at first precipitated; but afterwards the flakes adhering to the glass are slowly dissolved by the addition of more sulphuric acid, and a perfectly clear fluid, of a beautiful dark violet colour, is produced. (Virchow's *Archiv.*, vol. xiii; *Archives of Medicine*, vol. i, p. 346; Abstract of Kühne's Paper on *Icterus*, by Dr. G. Scott.)

6. *Evidence of Bile Obtained by Microscopical Examination.* If the urine contain any epithelial cells from the kidney, as is usually the case, microscopical examination of the deposit will at once show the presence of bile, as the cells have a bright yellow tinge. The existence of this tinge proves conclusively the presence of bile colouring matter; but its absence cannot be regarded as satisfactory proof of the urine being free from bile. In cases of kidney disease, when bile is present in the urine, the casts, when examined in the microscope, are seen to have a deep-yellow tinge.

Sugar.

Sugar is not present in healthy urine. Occasionally, however, traces of this substance are met with in the urine of persons who are not suffering from any particular symptoms. It may be excreted for days, or even for a few weeks at a time, in small proportion. It does not follow that all such cases are to pass into confirmed diabetes, but they should be carefully watched by the practitioner. Sometimes, after abstinence from food for some hours, a meal, consisting entirely of starchy matter, will cause sugar to appear in the urine, and if a person, under these circumstances, take a quantity of cane-sugar, a temporary diabetic condition will almost certainly be produced. Instances, in which sugar has been detected in the urine daily for several weeks, and recovery taken place, have occurred. Diabetes may last for many years, but generally it causes death in from one to four years. Although much light has been thrown upon the production of sugar in the animal body of late, no satisfactory explanation of these cases has yet been

offered, nor do we know anything of the condition of the system which precedes and ushers in the fatal form of diabetes.

Two kinds of diabetes have been described—*diabetes mellitus* and *diabetes insipidus*. I have already had occasion to allude to the latter, and have mentioned that in this condition large quantities of pale urine, containing little solid matter, and, it need scarcely be repeated, no sugar, are passed, it is therefore quite unnecessary to describe this condition as a distinct disease; the term *diabetes* should never be applied to it. Diabetes is sometimes called *mellituria* or *glucosuria*.

Diabetic urine is usually of a very pale colour, and possesses a peculiar odour, which has been compared to that of violets, apples, new hay, whey, horses' urine, musk, and sour milk. Such comparisons serve only to show how difficult it is to define, in words, a particular odour. No doubt all of you are well acquainted with this peculiar smell, which it is useless to attempt to describe.

Specific Gravity—Reaction. The specific gravity of diabetic urine is very high, almost always above 1030, and it sometimes reaches 1050. In some cases, however, the specific gravity does not differ from the healthy standard. Its reaction is generally acid, and sometimes its surface is covered with a whitish film, owing to the rapid development of the sugar fungus or torula. It has a sweet taste, and often attracts a great number of flies. This last circumstance is sometimes the first thing that directs the patient's attention to his water.

Deposits are not often met with in diabetic urine; those which have come most frequently under my own notice are deposits of the *phosphates*, and deposits of *uric acid*. The fixed salts are generally present in small quantity, and chloride of sodium is often altogether absent. The urea and extractive matters are, as a general rule, relatively much diminished in quantity; but in some cases they exist in considerable proportion. Lehmann states that diabetic urine always contains

hippuric acid, but Dr. Garrod fails to confirm his observations. The quantity of urine secreted by patients suffering from this malady is sometimes enormous, and in many cases this is the first point to attract attention to the disease. Some patients have passed as much as twenty pints of urine *per diem*, and P. Frank mentions a case in which the enormous quantity of fifty-two pounds was discharged in twenty-four hours. The proportion of solid matter varies greatly in different cases; it not unfrequently exceeds two pounds, the greater part of which is composed of sugar.

Diabetic sugar is easily obtained from the urine when but little urea and extractive matter are present. If some of the urine of specific gravity 1050, from a bad case, be allowed to evaporate at a temperature of 100°, small warty masses, of a rounded form, soon make their appearance. Under the microscope, these are seen to be composed of very beautiful crystalline plates. When a considerable quantity of the sugar

Fig. 6.—Crystals of Diabetic Sugar from Diabetic Urine containing very little Urea.

has crystallised, it may be washed with ice-cold water, well pressed between folds of bibulous paper, and dried over sul-

phuric acid. It is now, in many cases, nearly colourless, and, after two or three crystallisations, from distilled water, it becomes nearly pure. In fig. 6 some beautiful crystals of grape-sugar are represented. These were obtained by allowing a few drops of diabetic urine, containing a mere trace of urea and salts, to evaporate spontaneously on a glass slide. Similar crystals were obtained from the tears of the patient (case reported by Dr. Gibb, in *Archives of Medicine*, vol. i, page 250). Lately, I have obtained crystals from several specimens of diabetic urine. These crystals are very beautiful objects when examined by polarised light. I am not aware that they have been figured before.

Tests for Diabetic Sugar.

The presence of grape sugar in urine is readily ascertained by the application of certain tests, and if moderate care be taken in the examination, the detection of this substance is not open to many fallacies.

Moore's test for grape-sugar consists in adding, to the urine suspected to contain it, about half its bulk of liquor potassæ. If sugar be present, the mixture becomes of a rich brown colour upon boiling, which increases in intensity if the boiling be prolonged. The brown colour of the solution is owing to the formation of mellassic or sacchulmic acid; glucic acid is also produced in the decomposition. This test, however, cannot be depended upon for detecting the presence of small quantities of sugar, because there are some other substances besides sugar which will cause the development of the colour in a slight degree.

Trommer's test. Of all the tests which have yet been proposed, that originally suggested by Trommer, or some slight modification of it, will be found of the greatest practical value for showing the presence of sugar in diabetic urine, in clinical investigations. Trommer's test is applied as follows:—A small quantity of the urine, placed in a test tube, is to be treated with

solution of potash, and a drop or two of a solution of sulphate of copper is to be dropped into the mixture. If sugar be present in any quantity, the precipitate at first formed will be redissolved, and the solution will be of a *dark blue* colour. If only traces of sugar are suspected to be present, one drop of the sulphate of copper solution will be sufficient. The dark blue solution is now to be heated to the boiling point, and if sugar be present, a pale *reddish brown precipitate of suboxide of copper* is immediately thrown down. Instead of boiling the mixture, it may be allowed to stand for some time, when a similar deposit will gradually subside. If the suboxide is only reduced after prolonged boiling, this cannot be taken as good evidence of the presence of sugar, for under these circumstances there are some other substances which will cause the reduction of the oxide of copper. Again, if the solution simply *change colour* by boiling, *without the occurrence of a distinct precipitate*, we must not infer that the change is necessarily due to the presence of sugar, for almost all specimens of urine exhibit this change. A flocculent precipitate of earthy phosphate, which always takes place, cannot be mistaken for the suboxide, as it is quite colourless, or of a pale greenish tinge. The reaction alone characteristic is the production of a brown or yellowish precipitate (varying in quantity according to the amount of sugar the urine contains), either after the mixture has stood for some time, or upon boiling it not longer than for a minute.

Modifications of Trommer's test have been proposed by Barreswil, and others, the most applicable, however, according to Lehmann, being that of Fehling (Lehmann's *Physiological Chemistry*, by Day, vol. i, p. 288. Cavendish Society). As this test is more easily applied than the sulphate of copper and potash, it may be well to mention its composition,—69 grains of sulphate of copper are to be dissolved in 345 grains of distilled water; to this solution a concentrated solution of 268 grains of tartrate of potash, and then a solution composed of

80 grains of carbonate of soda in an ounce of distilled water are to be added; the mixture may be poured into a 1000 grain measure, and filled up with water.

Barreswil's solution is composed of the following constituents :—

Cream of tartar	.	96 grains
Crystallised carbonate of soda	.	96 „
Sulphate of copper	.	32 „
Caustic potash	.	64 „
Water	.	2 fluidounces.

In using these tests, it is only necessary to add about an equal bulk to the urine in a test tube, and then to boil the mixture. If sugar be present, the precipitate of suboxide occurs immediately. The application of this solution to the quantitative determination of sugar, will be considered under *volumetric analysis.* Trommer's, or one of the above mentioned modifications, will be found the most delicate test which can be used, when only small quantities of sugar are suspected to be present, and the tartrate of copper solution is applied as easily as the liquor potassæ test, while the results obtained from it are far more to be depended upon. If albumen be present, the reduction of the oxide of copper does not take place, so that in using the copper test we must ascertain that this substance is absent. Ammonia also dissolves suboxide of copper.

It has been shown that allantoin, creatine, and creatinine, have the power of producing a precipitate of suboxide of copper, like grape-sugar, and more recently, M. Berlin has proved that uric acid possesses to some extent the same property.

Sometime since I endeavoured to ascertain the cause of certain anomalous results, which were sometimes met with in employing this test; and as these to some extent explain the discrepancies of different authorities with reference to the presence or absence of sugar in the urine in certain cases, it is

well to allude to them here. The following results were obtained.

1. The precipitate of suboxide of copper was readily dissolved by acetic, hydrochloric, and nitric acids. It was also dissolved by ammonia.

2. The precipitate was insoluble in a solution of chloride of sodium, but was readily dissolved by a weak solution of chloride of ammonium.

3. The addition of a few drops of chloride of ammonium previous to boiling, entirely prevented the precipitation of the suboxide, the mixture retaining its greenish colour. Upon adding some solution of potash, however, the precipitate of suboxide was produced, and ammoniacal fumes were given off at the same time. If a moderate quantity of solution of chloride of ammonium was present, the precipitate did not occur upon the addition of potash, even after very prolonged boiling.

4. If a drop of a very dilute solution of the chloride of ammonium was added to a pretty strong solution of sugar, and, after the addition of the tartrate, the mixture was boiled, no precipitate took place, but the solution became of a pale brown tint; the suboxide being immediately thrown down upon the addition of a few drops of a solution of potash, with the development of ammoniacal fumes. In the above cases in which no precipitate took place, it was ascertained that there was the usual excess of alkali present in the test solution.

5. A solution of oxalate of ammonia also prevented the precipitation of the suboxide, but a greater quantity of this salt than of the chloride of ammonium was required.

6. A neutral solution of urate of ammonia (artificially prepared) also prevented the reduction of the suboxide, and dissolved the precipitate if added to it. On carrying out this experiment further, it was found that the *precipitate of suboxide of copper was dissolved by urine containing an excess of urate of ammonia.*

7. A solution of grape-sugar in water was prepared, and by a preliminary experiment it was ascertained that, upon being boiled with the tartrate test, an abundant precipitation of suboxide took place.

To a portion of the precipitate of suboxide produced in this way, about a drachm of healthy urine, immediately after it was passed, and while yet warm, was added, and the reddish precipitate was instantly dissolved, forming a perfectly clear solution. Upon further boiling, a slight precipitate of phosphate took place. The suboxide, however, could not be precipitated by the further addition of potash and prolonged boiling.

8. Upon mixing a small quantity of grape-sugar with the same specimen of healthy urine, and boiling the mixture with the tartrate test, *no precipitate*, except a little phosphate, was produced. About half an ounce of the same mixture of urine and grape sugar was placed in a test tube, mixed with six drops of yeast, and inverted over mercury. The whole was then placed in a temperature from 70° to 100° for about twelve hours, at the end of which time the tube was found quite filled with gas, and all the liquid was expelled into the vessel in which it had been placed. The specimen of urine with which the above experiments were tried, was allowed to stand in a still place; and when it had become quite cold, an abundant precipitate of urate of ammonia was found to be present.

9. A portion of the aqueous solution of grape-sugar was mixed with a strong solution of urate of ammonia (artificially prepared), and then a certain quantity of the tartrate solution was added, and the mixture boiled. The characteristic precipitate, or opalescence, was not produced, but the mixture became of a pale fawn colour. In a weak solution of urate of ammonia, the characteristic precipitate appeared after boiling the mixture for some minutes.

So that, although much sugar is present, the colour of the mixture may be merely changed to brown, and no precipitate whatever may take place.

10. A solution of grape-sugar was treated with a drop of a dilute solution of chloride of ammonium, and boiled with the tartrate solution. The mixture became of a brown colour, but no precipitate occurred. Upon the addition of a few drops of solution of potash, the precipitate of suboxide was produced.

A solution of grape-sugar, treated with Trommer's test, according to the usual method, behaved in the same way, in the presence of chloride of ammonium, as when treated with the tartrate of copper solution; but in this case a greater quantity of the chloride was necessary, for when only traces were present, ammoniacal vapours were given off, and the precipitate of suboxide subsided, as before remarked.

From the results of the above experiments, the following conclusions with reference to the practical application of Trommer's test, and Fehling and Barreswil's solutions, and other modifications of the copper test, may be drawn* :—

1. That if the urine contain chloride of ammonium (even in very small quantity), urate of ammonia, or other ammoniacal salts, the suboxide of copper would not be precipitated if only a small quantity of sugar were present.

2. That unless there be a considerable quantity of one of the above salts present (in which case the blue colour will remain), the mixture will change to a brownish hue upon boiling, but no opalescence or *precipitate* of suboxide of copper will occur. When only a moderate amount of sugar is present, I have been unable to obtain a precipitate, under these circumstances, by the addition of potash to the solution, and prolonged boiling. By observation 8, it appears that a specimen of urine exhibiting this reaction may contain a large quantity of sugar, as ascertained by the yeast test.

* Professor Brücke has recently drawn attention to the action of ammonia in preventing the precipitation of the suboxide of copper, and other points connected with this subject. Probably he had not seen the results just given, which were obtained in 1852, and published in the Med.-Chir. Review, Jan. 1853, vol. xi, p. 113.

3. That in many cases in which the precipitation of the suboxide is prevented by the presence of ammoniacal salts, the addition of potash to the solution, and subsequent boiling, will cause the production of a precipitate with the evolution of ammoniacal fumes. Hence care should always be taken that there is a considerable excess of free alkali present.

4. When only small quantities of sugar are present in the urine, and the precipitate of suboxide of copper is not decided, the fermentation test should be resorted to.

Upon treating different specimens of diabetic urine with Trommer's test, or its modifications, it has often been noticed that in one case the precipitate is produced as soon as the mixture reaches the boiling point, or even before; while in other instances it is necessary to keep it in active ebullition for some minutes, before any precipitate is produced. This circumstance receives explanation from the facts above detailed with reference to the presence of ammoniacal salts; and other anomalous results, which must have occurred to many in the habit of employing this test, become explained.

As a test for diabetic or grape-sugar, if proper precautions be observed, much greater dependance can be placed on this test than by simply boiling with liquor potassæ. Specimens of urine in which sugar is suspected to be present, and no decided precipitate of suboxide (which must be carefully distinguished from phosphate *) occurs, should be carefully fermented with yeast before any conclusion is arrived at.

On Testing for Sugar when only Traces are Present. In fluids which are suspected to contain only mere traces of sugar, it is necessary to separate some of the other constituents before applying the test. The plan recommended by M. Leconte is the following:—Excess of acetate of lead is added, and the precipitate separated by filtration. The solution is concentrated by evaporation, treated with ammonia, and

* The precipitate of suboxide may be distinguished from phosphate by its solubility in ammonia.

again filtered. The copper test is then applied. The objections to applying the reduction test to solutions containing ammonia has been already discussed. It is better to employ carbonate of potash, or soda, instead of ammonia. The excess of lead salt may also be removed from the filtered solution by passing sulphuretted hydrogen. The precipitate of sulphuret of lead is removed by filtration, and the liquid, after evaporation to a small bulk, may be tested.

Another plan recommended by M. Leconte is to treat the urine with acetic acid, and evaporate it to about the fifth of its bulk; it is then treated with alcohol, and after filtration from the salts, etc., the alcoholic solution is evaporated and tested. This plan is free from the objection that ammonia may cause the destruction of the sugar where only traces are present.

The Yeast Test. This is one of the most satisfactory tests for the presence of sugar, and if employed with proper care can hardly fail in its results. Two test tubes, of the same form, and of equal size, are to be taken. One is nearly filled with water, and into the other a corresponding quantity of the urine is to be poured. An equal amount of yeast is now to be added to the liquids in the tubes, and after pouring in just sufficient fluid to fill the tubes, the thumb is to be carefully placed over the opening, and the tube inverted in a small cup of mercury. The best plan, however, is to cut out a little india-rubber pad, slightly larger than the upper extremity of the tube. When the tubes have been filled up to the brim with a little water, the pad is allowed to float on the surface; next a little cup or beaker is inverted, and carefully placed over the end of the tube. The india-rubber being pressed against the open end, the fluid is prevented from escaping. The whole may be inverted, and a little mercury having been poured into the beaker, the india-rubber may be removed, with forceps, without any escape of the fluid. The tubes may be supported in position by a wire stand. Both tubes are then to be exposed, for a

few hours, to a temperature of from 80° to 90°, and the comparative size of the bubble of gas in the upper part of each may then be noted. If an appreciable quantity of sugar be present, the bubble of gas in the tube containing the urine will be many times larger than that in the tube which contains the yeast and water. In the latter tube the bubble of gas merely arises from the small quantities of air previously mixed with the yeast, becoming disengaged, and floating to the surface. Fermentation, when carefully performed, is positive evidence of the presence of sugar, although it does not indicate the kind of sugar present.

Maumené's Test. A little woollen rag, as merino, is cut into strips, and soaked for four or five minutes in a solution of perchloride of tin (one part of the perchloride to two parts of water). The slips are then dried over the water bath. A drop of the urine suspected to contain sugar is allowed to fall on a small slip of the prepared merino, which is then dried, and exposed to the dull red heat of a spirit lamp. If a trace of sugar be present, a black spot is produced.

Bismuth Test. Bottger has lately proposed a new test for sugar. This consists in adding first of all potash, then a small quantity of subnitrate of bismuth; lastly, the mixture is boiled. If sugar is present, the oxide is reduced to metallic bismuth, which is precipitated in the form of a black powder. It has been asserted that sulphuret of bismuth is formed, but this seems not to be the case. Brücke shows that this test is more delicate than Trommer's (or the modification of it by Fehling); and he finds that the black precipitate is produced to some extent in specimens of healthy urine. The bismuth test may be also applied thus. A solution of carbonate of soda (crystallised carbonate 1 part, water 3 parts) is prepared, and a certain quantity added to an equal amount of the urine. A little basic nitrate of bismuth is then added, and the mixture heated to the boiling point. If sugar be present, a black precipitate is produced.

Of Estimating the Quantity of Sugar. The quantity of sugar is easily determined, though not with absolute accuracy, by fermentation. The quantity of carbonic acid formed may be measured, weighed directly, or its weight may be determined by ascertaining the loss of weight the urine has sustained from fermentation.

Fermentation. If the carbonic acid is to be measured, the mixture of yeast and urine must be placed in a graduated tube inverted over mercury. When the fermentation is complete, which is generally the case in from six to twelve hours, at a temperature of 100°, the volume of gas may be read off, and, after correction for temperature and pressure (Miller's *Elements of Chemistry*, vol. i, pp. 48, 180), the amount of sugar calculated. One grain of sugar corresponds to nearly one cubic inch of carbonic acid.

The carbonic acid may be weighed by causing it to pass through a solution of liquor potassæ, specific gravity 1250, in an ordinary Liebig's potash tube. One grain of carbonic acid corresponds to about two grains of grape-sugar. The urine (about 500 grains) with the yeast may be placed in a small retort, to the end of which is adapted a chloride of calcium tube, or a tube containing pumice stone moistened with sulphuric acid, for the purpose of drying the gas. To the extremity of the drying tube the potash apparatus is connected. This is weighed just before and immediately after the fermentation, which should be allowed to proceed at a temperature of from 80° to 100° for twelve hours. The increase of weight is due to dry carbonic acid. Or, lastly, about 200 grains of urine with a little yeast are placed in a flask, to the mouth of which a small drying tube is adapted, as shown in fig. 7. The apparatus is to be carefully weighed before and after the experiment, and the loss indicates carbonic acid.

The results afforded by fermentation are not so accurate as those obtained by the volumetric process of analysis, which I shall describe in my last lecture.

Determination of Sugar by the Polarising Saccharimeter. Biot, many years ago, proposed a plan for estimating the proportion of sugar in fluids, depending upon the influence which the solution of sugar exerted upon a ray of polarised light made to pass through a thick stratum. Under these circumstances, a succession of colours is produced in the following order: *yellow, green, blue, violet, red.* If, in order to produce this series of changes, the hand must be turned towards the right, the solution is said to divert the plane of polarisation to the right, or to exhibit *right-handed polarisation;* but if to the left, *left-handed polarisation.* Cane-sugar and diabetic sugar have the

Fig. 7.—Flask containing the urine and yeast. The disengaged carbonic acid passes through the little tube containing chloride of calcium or fragments of pumice-stone moistened with strong sulphuric acid.

first property; the sugar of fruits the second. The amount of rotation varies according to the quantity of sugar present. Two or three different forms of apparatus have been made. Mitscherlich's and Soleil's are the best. A modification of Mitscherlich's, made for me by Mr. Becker, of the firm of Elliott, brothers, Strand, is represented in fig. 8. The urine or saccharine fluid is placed in the long tube. At the end near the lamp is a prism of Iceland spar, the *polariser;* and at the other extremity another prism, the *analyser.* The latter crystal

is connected with a moveable bar, which can be rotated with the hand, and the arc through which it is carried can be accurately measured on the graduated circle with the aid of a vernier. The instrument is placed with the posterior aperture

Fig. 8.—Polarising saccharimeter made by Mr. Becker.

about two inches from a homogeneous light,* and the prisms adapted to zero, which is found by arranging the posterior prism so that, the tube being empty, when the arm stands at zero, the little spectrum is quite dark. It is then ready for use. The tube is filled with the solution carefully filtered; and if dark coloured, it is to be decolorised in the first instance by animal charcoal. Upon moving the arm towards the right, it will be found that, after it has passed through a certain number of degrees, the colour of the spectrum becomes blue, and gradually violet and red. Now, the exact degree at which the colour passes from the violet to the red is to be noted; and the number will vary according to the quantity of sugar. The

* The best light is a very good argand or Leslie's burner, with a white porcelain reflector having a dull surface behind; or a piece of thin ground glass, or semi-opaque white glass, may be placed in front of the lamp.

value of each degree is ascertained by examining in the first instance a few solutions having known quantities of sugar dissolved. Supposing that 50 grains of sugar, dissolved in a certain quantity of water, require a rotation of 20°, 100 grains in the same quantity of fluid would require a rotation of 40° before the violet colour would appear. This method is very simple and accurate.

M. Clerget (*Annales de Chimie*, III, xxvi, 175) used Soleil's instrument, which was also employed by Dr. Bence Jones for determining the quantity of sugar in wines and in diabetic urine. (*Med. Times and Gazette*, vol. xxv, 1852, p. 102.) The apparatus consists of a polariser and an analyser, made of Iceland spar. The light, which should be bright, white, and homogeneous, is placed behind the polariser. Between the polariser and analyser is placed the tube containing the saccharine solution, as in the other apparatus. Before reaching the saccharine solution, the rays of light pass through a circular plate of quartz "composed of two half circles possessing equal and opposite rotatory power". The colour of the two plates will be the same before placing in the sugar, but afterwards the colour varies much; and by moving the compensator, composed of two wedges of quartz, which can be slipped over each other, the colour will be equalised. The amount of movement required, or the thickness of the quartz, varies according to the amount of sugar present; and thus the proportion may be determined.

Dr. Garrod's Plan of Estimating the Quantity of Sugar. Dr. Garrod has lately devised an instrument for estimating the quantity of sugar in urine, founded on the principle that the alteration of colour caused by boiling a mixture of diabetic sugar and carbonate of potash varies in intensity according to the quantity of sugar present. A standard solution is prepared of the colour produced by a solution containing half a grain of sugar to the fluidounce. This is placed in a clear glass tube of about half an inch in diameter. The solution of carbonate

of potash is prepared by dissolving four ounces of the carbonate in six ounces of water, and the solution filtered.

In the first place, Moore's test is applied; and if the colour produced after boiling for a few minutes be deeper than an amber red, it is necessary to dilute the urine before making the quantitative determination. The darker the colour produced, the more the urine is diluted. An equal bulk, twice or three times its bulk, of water is to be added, according to circumstances; the exact proportion added must, of course, be carefully noted.

Thirty minims, by measure, of the urine, diluted or not, as the case may be, are mixed with an equal quantity of the carbonate of potash solution, and poured into a small flask. The measure is to be washed out with about a drachm and a half of water, which is also to be mixed with the solution. Next, the whole is to be boiled over a spirit-lamp for five minutes. When cool, the mixture is transferred to a graduated tube of the same calibre as that which contains the standard solution, and diluted with water until its tint is exactly the same as that of the standard solution. By a simple calculation, the quantity of sugar is easily found. Suppose it has been necessary to make the urine by dilution, forty times its original bulk, in order to obtain the exact tint, it will contain forty half-grains of sugar per ounce, or twenty grains of sugar. From these data, the proportion passed in the twenty-four hours is easily calculated. The apparatus was made by Messrs. Coxeter.

Circumstances under which Sugar is excreted in the Urine. Although of late years many new and important facts connected with the formation and destruction of sugar in the healthy organism have been discovered by Bernard, and verified by many observers, the pathology of diabetes is still obscure. There can, however, be little doubt that the sugar is formed in the liver, principally from albuminous substances; but whether its excretion in such large quantity depends upon increased

activity of the actions concerned in its production, or arises from the cessation of the destructive changes which occur in a normal state, has not been determined. Neither can we say how far the affection may be influenced by the state of the nervous system. Nevertheless, very much has been done by physiologists in this direction; and I think we are justified in feeling sanguine that in a few years the nature of this wonderful and fatal disease will be revealed.

I do not propose to enter upon the subject of the treatment of diabetes, although we may consider some of the circumstances which cause an increase or diminution in the quantity of sugar excreted. Diabetes is often only of temporary duration, and we know that many persons for a time pass small quantities of sugar in the urine without even being aware of the occurrence. In other instances, diabetes may persist for some time, and then pass off. In many cases, the diabetic condition lasts for a certain time, passes off, and after an interval reappears. The disease may continue for many years, or may carry off the patient in a few months. The urine is, as before remarked, usually of high specific gravity; but sometimes urine containing sugar is not more than 1015. The reaction is generally acid, often excessively so. The quantity of urea varies much in different cases; usually it is diminished, but a large quantity of this substance, as well as sugar, is sometimes excreted. In one of Dr. Garrod's patients, as much as 1085 grains of urea and 3500 grains of sugar were eliminated in twenty-four hours. The observation of Lehmann, that diabetic urine does not contain uric acid, is undoubtedly erroneous; for, in this country at least, it is not uncommon to meet with an abundant deposit of this substance. Dr. Prout regarded the presence of uric acid as a favourable sign. Hippuric acid is said to be present in diabetic urine (Lehmann and others); but in some specimens of urine, in which Dr. Garrod sought for it, he failed to detect it. (*Gulstonian Lectures*, BRIT. MED. JOURNAL, 1857.)

The highly important and interesting observation lately made

by M. Hohl, in a case of diabetes where inosite was passed in large quantities, and seemed to take the place of the urea and sugar, must not be passed over. I shall have occasion to recur to this very shortly.

The quantity of sugar, as you know, is much influenced by the quantity and nature of the food. It increases shortly after a meal, and it is undoubtedly augmented when much starch is taken. A meat diet, with bran or gluten bread, always causes a diminution of the sugar. Total abstinence from food, and rest, diminish the proportion; and it is increased by exercise, and favoured by a large quantity of food. As much as two pounds of sugar may be excreted daily; but about one pound is the more usual quantity. I have now under my care a girl, aged 19, who excretes daily about one pound and a half of sugar.

The dry harsh skin, the intense hunger and thirst, the emaciation, the tendency to the formation of tubercle in the lungs and other organs, are familiar to all who are acquainted with the clinical history of this disease. Dr. Garrod observes, that œdema of the legs is always present in diabetes. Although in some cases it is very slight, he states that it is always to be detected.

In extreme cases of phthisis, sugar is occasionally detected in the urine; and towards the close of many exhausting diseases, a meal of starch is followed by the excretion of saccharine urine. It has also been detected in severe disease of the respiratory organs, as pneumonia and bronchitis. I have proved the presence of a considerable quantity of sugar in the sputum, in a case of acute pneumonia, just before the patient's death. It has been asserted by some observers, that sugar can always be detected in the urine after anæsthesia produced by chloroform, and in cases of bronchitis and emphysema. I have carefully tested for sugar in the urine of several patients who had taken chloroform, but did not succeed in detecting it in a single instance. The presence of the sugar is accounted for under

these circumstances, on the supposition that in disease of the pulmonary organs the sugar is not further oxidised, and carried off as carbonic acid. But Bernard has shewn that this theory has no foundation, and has proved that the condition of temporary diabetes produced by irritation of the floor of the fourth ventricle, close to origin of the pneumogastric nerves, is not due to the impaired action of the respiratory organs, as Reynoso and others have supposed.

Bernard has brought forward various facts which militate against the above view; as, for instance, no sugar appears in the urine after complete section of the pneumogastric nerves, and in many other conditions where the respiratory function is impaired. Nevertheless, Reynoso (*Comptes Rendus*, t. xxxiii, xxxiv) states that sugar is present in the urine of persons who have been placed under the influence of chloroform, bichloride and iodide of mercury, salts of antimony, opium and narcotics generally, quinine, and carbonate of iron. He also states that in pleurisy, asthma, and chronic bronchitis, hysteria, and epilepsy, he discovered sugar in the urine. The test employed, it is very important to observe, was Barreswil's solution; but, before applying it, the extractive matters were removed. About 1500 grains of the urine to be tested were treated with a solution of subacetate of lead. The precipitate was collected on a filter, and the excess of lead salt in the filtrate was decomposed by chloride of sodium; and the solution was again filtered. The clear fluid, after being concentrated, was treated with the copper solution. To another portion the yeast test was applied.

Michèa, who, it should be observed, employed Moore's test, failed to confirm the above conclusions. Dèchambre (*Gazette Mèdicale*, 1852) found sugar in specimens of urine obtained from several old people. The test employed was the same as Reynoso used, except that the excess of acetate of lead was decomposed with carbonate of soda instead of chloride of sodium. Dr. Bence Jones obtained "slight but distinct" evi-

dence of the presence of sugar in the urine of a patient who had been twenty-four hours under the influence of chloroform. The urine was examined according to Reynoso's directions. M. Blot also confirms Reynoso's observations to a great extent. He found sugar in the urine of pregnant women, and in those who are suckling children as soon as the milk was secreted. It is possible that affections of the respiratory organs may be instrumental in producing the diabetic condition; but this may be due to the excitation of the peripheral extremities of the pneumogastrics, depending upon the altered state of the pulmonary membrane, being propagated along the trunks of nerves to that particular part of the medulla oblongata the artificial irritation of which in animals is known to induce diabetes. There are many facts which support the doctrine that the processes concerned in the production of the sugar are capable of being excited in a reflex manner, and they may therefore be included in the excito-secretory actions.

These observations of Reynoso and others seemed to be so important that it was very desirable to repeat them. I therefore tried numerous experiments, but was unable to confirm the results. I often found the fluid change to a brown colour when heated with the copper solution; but, as I have shown, this is not a proof of the presence of sugar. I never conclude that sugar is present in a specimen of urine, unless a decided precipitate of the suboxide of copper is produced. Though this *precipitate* be very slight, it is characteristic. If it only amount to an opalescence, as I have before stated, it is sufficient; but a change of colour even to a dark brown, the solution still remaining clear, does not, I believe, indicate the presence of sugar.

These unsatisfactory results led me to institute the experiments upon the action of Barreswil's and Fehling's solutions, and different forms of the copper-test, which have been already described.

The Experiments of Reynoso and Déchambre repeated, with

Negative Results. The urine was tested as in Reynoso's experiments, except that carbonate of soda was used to precipitate the excess of subacetate of lead, instead of chloride of sodium. The specimens of urine passed by six patients under the influence of chloroform, for periods of time varying from ten minutes to half an hour, that of an old lady aged 87, of an old man aged 96, and of two children suffering from epilepsy, were carefully examined. In most, the solution became brown upon being boiled; but no opalescence or precipitate was produced. The urine of a healthy man, aged 24, was also subjected to examination, and became brown upon being boiled with the copper test. The results of numerous other experiments upon specimens of urine known to contain no sugar led me to the conclusion that, in all the above cases, the urine was perfectly free from this substance. Kletzinsky has repeated Reynoso's experiments, and has failed to confirm his conclusions. Dr. Moore of Dublin (Heller's *Pathological Chemistry of the Urine,* translated by W. D. Moore, A.B., M.B.T.C.D) has examined the urine of twelve men and women whose ages varied from sixty to eighty-three, but was unable to detect sugar. We may, therefore, conclude that there is at present not sufficient evidence to prove that sugar is *habitually* excreted in the urine of old people, or by patients suffering from chest-disease, or by those under the influence of chloroform, etc. It is probable that it may be occasionally met with in some of the above cases.

Analyses of Diabetic Urine. It is difficult to estimate the urea in diabetic urine by the old process; but the proportion may be ascertained by the volumetric method, which will be described in a future lecture. The following analyses show the composition of the urine in some cases of diabetes.

47. Urine from a girl aged 19. Specific gravity, 1037; acid, clear, pale.

48. From the same. Specific gravity, 1036; acid.

49. From a man aged 30, about one month before death. Specific gravity, 1023.

50. From a woman aged 28, a week before death. Acid; specific gravity, 1027.

51. From a patient who was passing sixty ounces of urine daily. Reaction acid; specific gravity, 1021.

Analyses.

	47		48		49	
Water . .	916·50		894·90		946·8	
Solid matters .	83·50	100	105·10	100	53·2	100
Urea . .						
Extractives .			82·29	78·2		
Uric acid .						
Alkaline salts						
Earthy salts	10·66	12·96	3·82	3·63	5·44	10·22
Sugar .	not estimated.		18·99	18·08	20·24	38·04

	50		51	
Water . . .	934·2		946·00	
Solid matter . .	65·8	100	54·00	100
Urea . .				
Extractive matters	16·94	25·74	21·54	39·18
Uric acid . .	1·64	2·49		
Alkaline salts				
Earthy salts .	5·82	8·84	3·76	6·96
Sugar . .	41·40	62·91	28·50	52·7

Analyses 52, 53, 54 represent the composition of the urine in a case of diabetes now under my care in the hospital. The patient was a healthy looking girl, only eighteen years of age. She had been suffering from the disease for about three months. Various plans of treatment were tried, without any marked results. She remained under treatment for six weeks, and then left the hospital; but she will probably again come under our notice in a short time. She drank from four to six pints of fluid daily; and, when living on a moderate meat diet, with a small quantity of bread, passed rather under a gallon of urine. The urine was analysed from day to day; and I select three specimens for illustration. When the last was obtained, her diet was restricted to bran-biscuits and milk. The results are expressed in grains, and represent the quantities passed in twenty-four hours. [*See Table, next page.*]

Analyses.

	52		53		54	
	March 20th.	In 100 of solid matter.	April 2nd.	In 100 of solid matter.	April 23rd.	In 100 of solid matter.
Quantity of fluid drank in 24 hours	64708·75		36968·75		36968·75	
Specific gravity	1037		1043		1043	
Reaction	Acid.		Acid.		Acid.	
Water	78653·75		69364·50		50857·625	
Solid matter	8846·25		8510·50		6017·375	
Urea			512·20	5·430	455·000	7·561
Sugar	8750·00	98·910	7549·12	88·703	4889·326	81·253
Organic matter			141·07	2·447	501·287	8·333
Fixed salts			308·11	3·620	171·762	2·853

Let me now refer very briefly to some other *soluble substances* not present in healthy urine, which have been detected lately in small quantities in certain morbid specimens. These are, *leucine*, *tyrosine*, *inosite*, *acetone*, and *cystine*.

Leucine.

Leucine occasionally occurs as a deposit from the urine; but more generally it is held in solution, and can only be obtained by concentration of the fluid when it crystallises out in the form of small spherules, which are composed of acicular crystals which radiate from a common centre. This substance has of late been found in many of the solids and fluids of the animal body. It is not very soluble in water (one part in twenty-seven), but more so in alcohol. It crystallises from aqueous solutions, for the most part in spherical masses, which exhibit a radiated arrangement. From alcohol, leucine is deposited in the form of pearly scales, somewhat resembling cholesterine; but these are composed of small sphericles. Dry leucine can be sublimed without change. Leucine has been found in the saliva, pancreatic juice, and in the pulmonary tissue of the ox (Cloetta, *Chemical Gazette*, 1856, p. 61). Frerichs and Städeler have detected leucine in the blood, urine, and bile of patients suffering from typhus, small-pox, and other exanthemata. Dr. Thudichum found leucine in the urine of a man whose liver yielded a large quantity of it (*Treatise on the Pathology of the Urine*, 1858). It was obtained by concentrating the urine. This substance is probably formed in the liver, and in health rapidly converted into other compounds. In certain diseases, it is to be detected in very considerable quantity. Crystals of leucine may often be seen in sections of livers of patients who have died of jaundice. Frerichs has given several figures of leucine crystals in the liver, and also in the urine (*Pathologisch-Anatomischer Atlas zur Leberkrankheiten*, von Dr. F. T. Frerichs, Braunschweig,

1858). It occurs especially in the urine of patients suffering from acute yellow atrophy of the liver.

No satisfactory tests for leucine are yet known. If it can be obtained pretty pure by repeated recrystallisation, the dry leucine may be sublimed. The sublimate, composed of aggregations of rhombic plates, could not be mistaken for anything else. Urate of soda and many other substances crystallise in spherical globes, like leucine. Crystals of this form, however, which are soluble in alcohol, and again crystallise in spherules from an aqueous solution, can hardly be anything but leucine. This substance cannot, therefore, be recognised by the form of the crystals alone.

Fig. 9.—Crystals of Leucine. Those represented at *a* were crystallised from water. The rest were obtained from an alcoholic solution.

On obtaining Crystals of Leucine from the Urine. The extractive matters often interfere with the crystallisation of the leucine from urine, and the concentrated extract often remains for days without undergoing any change. Frerichs (*Klinik der Leberkrankheiten*, Band I, s. 221) recommends that the concentrated urine should be digested for some time with cold

absolute alcohol. By this means, the extractive matters are gradually dissolved out. The residue is then to be treated with boiling spirits of wine; and leucine crystallises out as this solution cools. It may be purified by recrystallisation. The extractive matter may be in great part separated by precipitation with acetate of lead.

Tyrosine.

This substance has been detected in the urine of typhus fever by Frerichs and Städeler. Like leucine, it is probably produced in the liver. It has been detected in this organ by Frerichs, Dr. Thudichum, and many other observers. It has been extracted from several animal fluids. Tyrosine crystallises in long white needles, and is very slightly soluble in cold water. It is dissolved by boiling water, alcohol, ether, the mineral acids, and alkalies. It may be prepared by boiling

Fig. 10.—Crystals of Tyrosine from a solution in boiling water.

horn, feathers, or hair, with sulphuric acid for forty hours. The dark brown liquid is to be made alkaline with milk of lime, warmed, and then filtered. Sulphuric acid is added to

neutralisation, and crystals are deposited upon evaporating the liquid. A very delicate test for this substance has been proposed by Hoffman. A solution of nitrate of protoxide of mercury, nearly neutral, is to be added to the solution suspected to contain tyrosine. If this body be present, a reddish precipitate is produced, and the supernatant fluid is of a very dark rose colour. Tyrosine crystallises in long white needles, which are aggregated to form brush-like masses. De la Rue found tyrosine in the cochineal insect. This is doubtless one of the substances resulting from the disintegration of albuminous substances. I have found it in considerable quantity in urine which contained much uric acid, and had been left to stand in a warm place for many weeks.

Inosite.

Inosite was discovered by Scherer in the juice of muscle, after the creatine and creatinine had been separated. It is termed muscle-sugar, and may be obtained in the form of colourless prismatic crystals, which are efflorescent. Inosite does not reduce the oxide of copper to the state of suboxide, as is the case with diabetic sugar and grape-sugar. It tastes sweet, and has the same composition as the latter substance. Inosite may be detected by evaporation nearly to dryness in a platinum basin, when, if a little ammonia and chloride of calcium be added, a rose colour is produced, especially if the mixture be again concentrated by evaporation.

Cloëtta has found inosite in the urine in Bright's disease, but has failed to detect it in the healthy secretion. He has discovered it in the lungs, liver, spleen, and kidneys. The lungs also contain traces of uric acid, taurine, and leucine. M. Hohl has lately recorded a case of diabetes in which a large quantity of inosite was obtained from the urine (*Gazette Hebd. de Méd. et de Chir.*, 1859, p. 221; *Journal de la Physiologie*, No. vi, p. 344). In this case, the proportion of sugar gradually dimi-

nished, and at the same time the quantity of urea excreted became less, while the inosite gradually increased in amount until upwards of *three hundred grains* of this substance were passed in the twenty-four hours. This observation is one of great interest in connexion with the pathology of diabetes.

Acetone.

Dr. Petters, at the suggestion of Dr. Lerch of Prague, sought for acetone in the urine of a case of diabetes, and discovered it both in the blood and urine (*Vierteljahrsch. für die Pract. Heilkunde*, Prag, 1857, vol. iii, p. 81). The peculiar smell of diabetic urine is to be attributed to the presence of acetone, according to this observer (Thudichum, *Pathology of the Urine*, p. 315).

Cystine.

Cystine is found in a state of solution in the urine in some cases, although it more usually occurs as a deposit. We shall therefore consider it more particularly under the head of urinary deposits. Julius Müller (*Archiv der Pharmacie*) obtained some urine from a boy 6½ years of age, which contained cystine in solution. The urine was alkaline. The cystine was precipitated in the crystalline form by the addition of excess of acetic acid. Crystals of cystine are represented in Plate x, figs. 1, 2, 3, 4, of *Illustrations of Urine, Urinary Deposits, and Calculi.*

I have ventured to occupy some time in drawing your attention to the characters of certain substances the presence of which in urine has only very recently been demonstrated. Probably, when the various materials removed in this excretion shall have been more thoroughly investigated, and when we know more relating to the precise conditions under which they are formed in the animal economy, the treatment of many diseases will be placed on a sounder basis, and we shall

be able to relieve sufferings and prevent the progress of morbid changes over which we have now very little control. It is true, there are many who consider all this minute scrutiny and scientific investigation as useless, or at least unnecessary and unpractical. This is a state of mind which it is difficult to understand; for it seems to me perfectly certain that the more minutely our investigation of diseased processes is carried out, the more we shall know about them, and the better able shall we be to suggest plans of treatment to combat the abnormal changes. That all this will ultimately lead to great practical results in treatment, I believe most sincerely; and I feel that any amount of time devoted to such researches is usefully and advantageously spent. If, then, I have tired you with some of these chemical details, my earnest belief that they are useful to the progress of medicine, and the desire, therefore, to see you prosecute such researches, must be my excuse.

In the next lecture, I shall have to describe the character of casts of the uriniferous tubes, which varies much in different renal diseases. But it is not possible to discuss this subject profitably without referring to many points connected with the anatomy of the kidney; and I therefore propose to give a brief outline of the anatomy of this organ, and especially of those parts concerned in the formation of casts.

LECTURE VI.

THE ANATOMY OF THE KIDNEY. ITS ACTION IN HEALTH AND DISEASE. *Cortical and Medullary Portions of the Kidney. Pelvis. Mammillæ. Infundibula and Calyces. Artery. Vein. Nerves. Lymphatics. Secreting Apparatus. The Uriniferous Tube. Of the Circulation in the Kidney. Epithelium. Of the Basement Membrane of the Tubes and of the so-called Matrix. On some Points connected with the Physiology of the Kidney.* ON THE FORMATION OF CASTS OF THE URINIFEROUS TUBES. *Of the Cast. Circumstances under which the Renal Secretion may be altered in Quantity or Quality. On the Absorption of Substances from the Stomach, and their Excretion in the Urine.* MORBID CHANGES AFFECTING THE STRUCTURE OF THE KIDNEY. *Of Bright's Disease. Dr. Johnson's Investigations.*

GENTLEMEN,—I propose to devote some time this evening to the consideration of the anatomy and physiology of the kidney, and I hope to be able afterwards to give you a short account of some of the most important morbid changes to which this gland is liable.

As the kidney is essentially concerned in the removal of soluble substances resulting from the disintegration of tissue, the accumulation of which in the blood would materially interfere with the action of other important organs, it must necessarily form an interesting subject of study for the physician. It is not too much to say that, without a good knowledge of the anatomy and physiology of the kidney, it is impossible to form an accurate idea of the nature of a large class of diseases.

A thorough acquaintance with the physiological changes occurring in this organ will alone enable us, to the greatest advantage of our patients, to suggest and apply remedies in various cases of disease. The subject is so extensive that I cannot hope to do more than offer some very brief remarks; and I shall omit discussing many points connected with the pathology necessary to make the subject complete, because your practical knowledge of disease renders such a minute description superfluous.

The general anatomy of the kidney is shown in section in the diagram (Fig. 11). Each kidney is enclosed in a capsule composed of fibrous tissue, but abundantly supplied with blood-vessels, and with lymphatics. At the hilus or notch, the capsule is continuous with the areolar tissue which surrounds the large vessels, and extends in intimate relation with them for a certain distance into the interior of the organ.

The *cortex* or *cortical portion* of the kidney consists of a layer about half an inch in thickness, forming the surface of the entire organ, and dipping down often to the depth of an inch between the pyramids.

The *medullary portion* lies immediately within the cortex, and is directly continuous with its inner surface. It is composed of from ten to fifteen pyramids, their bases being continuous with the cortex; their apices free, and projecting into the cavity in the interior of the organ (*pelvis of the kidney*).

Pelvis: Mammillæ: Infundibula: Calyces. The mucous membrane, with the fibrous and muscular tissue externally, forms a dilated cavity in the interior, called the pelvis. From the pelvis, passing towards the apices of the pyramids, are several tubular prolongations, forming funnel-shaped channels (infundibula), usually not more than twelve in number. In many cases, two pyramids open into one infundibulum. Each of these funnel-shaped prolongations forms a cup-like cavity round the tip of the pyramid (*mammilla* or *papilla*), called a

calyx. Lastly, the mucous membrane, after forming this reduplication, is firmly adherent to the mammillæ, and immedi-

Fig. 11 shows the general structure of the kidney as seen upon section. The *ureter* traced upwards is continuous with the pelvis of the kidney. From the *pelvis*, narrow funnel-shaped prolongations (*infundibula*) are observed. These extend to the *pyramids*, being reflected around the apex of each to form a cup-shaped depression (*calyx*). The apices of some pyramids are also seen opening into the infundibula towards the observer. The *cortex* extending round the kidney and passing inwards between the pyramids, is easily distinguished from the *medullary portion*, by the irregular granular appearance it presents to the unaided eye, and by the numerous minute points (*Malpighian bodies*) seen in it. The medullary portion is composed of the pyramids, which consist of tubes which are nearly straight, and converge to the apex or *mammilla*, where they open by about fifteen or twenty orifices. Portions of arteries and veins are observed between the infundibula, and smaller vessels are seen in the section between the cortex and medulla. These give branches in two directions, *outwards* to the cortex, and *inwards* to the pyramids. The drawing is about two-thirds of the natural size. The scale at the side is divided into four spaces, representing inches.

ately continuous with that lining the tubes, which open by orifices varying from ten to twenty or more in number upon

the summit. Some of the free extremities of the pyramids are thin, and extend in a longitudinal direction perhaps for the distance of a quarter of an inch or more. The term mammilla or papilla can hardly be properly applied to these.

The pelvis is dilated at the notch or hilus, where it leaves the kidney, and soon contracts to a tube with muscular parietes (ureter), which opens into the bladder—one on each side of this viscus, at its posterior aspect.

Fig. 12.—Thin section of a portion of the kidney. *a*. Cortical, *b*. Medullary portion. *c*. Pelvis. *d*. Infundibulum. *e*. Opening of an infundibulum into pelvis. *f*. Calyx. *g*. Pyramid. *h*. Mammilla or papilla. *i*. Adipose tissue. *k*. Large veins divided in making the section. Small arteries are also seen cut across in different parts of the section, some large branches being situated between the cortex and medullary portion of the organ.

Artery. Outside the mucous membrane of the pelvis of the kidney, the artery, entering at the hilus behind the vein, divides into branches, which are distributed to the organ. The branches of the artery do not anastomose, but radiate outwards as they divide and pass towards the cortex. Arrived at a point between the cortical and medullary portions of the kidney, many branches pursue for some distance a more or less horizontal, or rather curved course, corresponding

to the bases of the pyramids. From these, radiating outwards in the cortex, pass a number of nearly straight branches, which give off on all sides little vessels which terminate in Malpighian bodies. The great bulk of the blood carried by the artery to the kidney is distributed to Malpighian bodies; but a few small arterial branches pass straight through the cortex, and supply the capsule; others are distributed upon the external surface of the pelvis, and ramify amongst the adipose tissue in the neighbourhood; while some (*vasa recta*) are given off from the vessels that lie between the cortex and medulla, many branches of which, I have shown, anastomose with each other, and pass in the substance of the pyramids towards their apices.

The emulgent or renal vein is formed by the union of a number of smaller trunks which receive the blood from the capillaries. Numerous large branches may be seen in the intervals between the cortex and medulla. They converge from all points, receiving the blood distributed by the artery as above described, and at length form one large trunk, which emerges at the hilus at its anterior part, and opens into the inferior cava.

Nerves. The nerves are branches of the sympathetic, and are distributed upon the coats of the artery. They may be traced for a considerable distance into the interior of the gland, always accompanying the subdivisions of the artery. I have seen branches on the Malpighian arteries, but have not been able to ascertain how they terminate. It is possible that small branches may pass into the Malpighian tuft.

Lymphatics. There are numerous lymphatic vessels distributed to the kidney. They leave the organ at the hilus, where the large vessels enter. I have not succeeded in injecting these lymphatics as I have in the case of the liver, where they exist in great number, and are found both in the substance of the capsule and in the portal canals. The capsule of the

kidney is probably also supplied with lymphatics, although it is not easy to demonstrate them by injection.

Secreting Apparatus: Uriniferous Tubes. The secreting apparatus consists of tubes lined with epithelium. The tube commences in a small flask-like dilatation, which embraces the capillary vessels of the Malpighian tuft (Fig. 13). In continuation with this is the tube which, in the greater part of its extent, is very much convoluted, being frequently bent upon itself; so that a great length of secreting tube occupies but a very small space. The convoluted tubes are so closely packed, that it is impossible to trace the course of one individual tube for any great distance; and, in thin sections of the cortex, segments of the windings of different tubes are seen divided in all directions.

The tubes, as they are about to leave the cortex, pursue an almost straight course; and here commences the ductal portion of the urinary apparatus. A certain number of these straight tubes extend nearly to the surface of the kidney, and carry off the secretion from the tubes which lie most superficially. These may be seen lying in the cortex, at certain intervals. In the pyramids, the tubes are straight; and as they converge, they unite together, and become fewer in number; while their calibre greatly increases as they pass towards the apex of the pyramid, where they open as before described. Some of these orifices are figured in Plate XXII, Fig. 5, vol. i, *Archives of Medicine*, 1859.

The *cortex* of the kidney, then, is composed of Malpighian bodies, the flask-like dilatations and convoluted portion of the uriniferous tubes with capillaries, the arrangement of which will be presently considered, branches of arteries and veins, with a certain amount of transparent and fibrous tissue.

The *medullary portion* is composed of the pyramids, which are formed of the straight portion of the uriniferous tubes, with capillaries, bundles of small straight branches (vasa recta) from the arteries, and numerous straight branches of

small veins; the majority of these nearly straight vessels, however, consist of vessels resulting from the division of the efferent vessels of the Malpighian bodies situated nearest the

Fig. 13.—The arrangement of the secreting structure and vessels of the kidney of man, magnified about 50 diameters. *a.* Malpighian body. *b.* Malpighian artery or afferent vessel. *c.* Efferent vessel. *d.* Capillary network, into which the blood passes from the efferent vessel. *e.* Small venous radicle, which carries off the blood after it has traversed the capillaries just alluded to. *f.* Commencement of the uriniferous tube by a dilated extremity, which embraces the vessels of the tuft. *g.* The tube; near the point where it opens, joins others, *h,* to pursue a straight course towards the pyramids of the kidney. *i.* Another tuft, the vessels of which are empty and shrunken. *k.* Portion of a tube cut across, showing the basement-membrane. The attention of the reader is particularly directed to this figure.

pyramids (Fig. 14). There is also an intervening material containing nuclei and having a very firm consistence.

Circulation in the Kidney. By the aid of Fig. 13, we may now trace the course of the circulation in the kidney. Starting from the arterial branches between the cortex and medullary portion of the organ (Fig. 12), the blood pursues two directions—*outwards* towards the external surface, and *inwards* towards the apices of the pyramids.

Of the blood which passes *outwards*, a little is distributed to the capsule and membrane of the pelvis, but by far the larger proportion is carried to the Malpighian bodies. Arrived at the Malpighian body, the trunk of the little artery divides into three or four dilated branches, each being as wide as the artery itself, which subdivide into capillary loops having their convexity towards the uriniferous tube, and which lie uncovered by epithelium within its dilated commencement; so that fluids passing through the membranous walls of these capillaries, and, indeed, everything escaping from them when they are ruptured, must at once pass into the uriniferous tube. The blood is collected from the capillaries by small venous radicles which lie in the central part of the tuft, which there unite to form a single efferent vessel that emerges usually at a point very close to that by which the artery entered. In some specimens, I have seen two and even three efferent vessels, but these are not common.

The *efferent* vessel of the tuft pursues a short course, and then divides into an extensive network of capillaries, in the meshes of which the tubes ramify. It is from the blood, which, after passing through one system of capillaries in the tuft, thereby losing much of its water, slowly wanders in a more concentrated state, through this second extensive capillary system, that the solid constituents of the urine are separated by the agency of the epithelial cells lining the tubes. The water transuding from the capillaries of the Malpighian body is made to traverse in succession the epithelial cells lining the tube, and dissolve the different substances which they have separated from the blood. It becomes richer and richer in

solid constituents as it approaches the straight portion of the tube. From the network of capillaries above alluded to, the blood is collected by small venous radicles, which at last pour their contents into the renal or emulgent vein.

Of the comparatively small quantity of the blood which passes *inwards* towards the apex of the pyramids, a very small portion passes into vessels which supply the walls of the pelvis and adipose tissue. The remainder is conducted towards the apex of the pyramid by the *vasa recta*, or branches resulting from the division of small trunks of the artery, one of which is represented at *a*, Fig. 14. These *vasa*

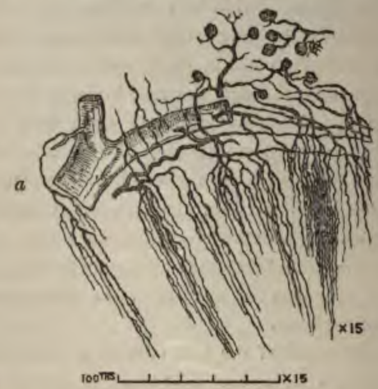

Fig. 14 represents the so-called *vasa recta*. Some of these straight vessels are seen to spring immediately from small arteries, but the greater number are formed by the division of the efferent vessels of the Malpighian tufts situated near the medulla.

recta terminate in a capillary network, in the longitudinal meshes of which the straight portions of the tubes lie. I have shewn that the vasa recta have the structure of small arteries; and, in disease, their coats are found much thickened, and the circular fibres very distinctly marked. It must not be concluded, however, that all the straight vessels in the pyramids are vasa recta; for the efferent vessels of those tufts near the

pyramids divide into long and nearly straight branches, which pour their blood into this system of capillaries, from which it is collected by radicles which also pursue a straight course, and unite together to form small trunks, which open into branches of the vein lying between the cortical and medullary portions of the kidney. It should be mentioned, that the intertubular capillaries are everywhere continuous; and from this network venous radicles arise at certain intervals. The arrangement of the capillaries is well shown in the frontispiece of the *Illustrations of Urine, Urinary Deposits, and Calculi.* Virchow seems to consider that all, or very nearly all, the straight vessels consist of vasa recta; but I have shown by transparent injections that many of these vessels are the efferent vessels from Malpighian bodies, as Bowman long ago stated. Some, however, certainly come directly from arteries (Fig. 14). ("On the Vasa Recta in the Pyramids of the Kidney," by the author—*Archives of Medicine*, No. IV, 1859.)

Epithelium. The epithelium of the kidney is represented in the annexed cut. That in the convoluted portion of the tube is described as being polygonal; it extends into the tube to the extent of one-third of its calibre. That in the straight portion of the tube is flatter, and approaches to the scaly variety of epithelium. Although the convoluted portion of the tube is much

Fig. 15.—Epithelium from the convoluted portion of the uriniferous tube. *a.* Treated with acetic acid. × 215.

wider than the straight portion, the diameter of the channel is much wider in the latter position than in the former, owing to the much greater thickness of the epithelium in the secreting portion of the tube.

In healthy human kidneys, I have never seen the outline of the cells so distinctly as figured in various works, or in the upper part of my own figure. The round body usually termed the nucleus is very clear and well defined, and this seems to be surrounded by a quantity of soft granular matter. I think it very doubtful if there is a cell-wall external to this. In many cases of disease, the round central body is all that can be made out; and sometimes these are found in great number in the urine. By the action of acetic acid, nucleoli may be observed. It would seem as if the granular matter external to the rounded granular body (nucleus) was altered in character under certain circumstances. From numerous observations, I feel compelled to dissent from the descriptions generally given both of the kidney and liver epithelium, inasmuch as the appearance of a cell-wall can only be seen under certain circumstances; and in many animals there is undoubtedly no such structure. I would rather say that the so-called nuclei are imbedded in a granular material, by which they are separated from each other by nearly equal distances, as represented in the lower part of Fig. 15.

16

17

Fig. 16.—Epithelium from the pelvis of the kidney.
Fig. 17.—Epithelium from the ureter.

The epithelium in the straight portion of the tube is much flatter than that in the convoluted part, and probably serves the office of a protective covering. It is doubtful if it takes part in secretion.

The Basement-Membrane of the Tubes and the so-called Matrix. The basement-membrane is easily demonstrated by washing a thin section of the kidney, so as to remove the

epithelium. It is much stronger and thicker in the pyramids than in the cortex (Fig. 20, *b*).

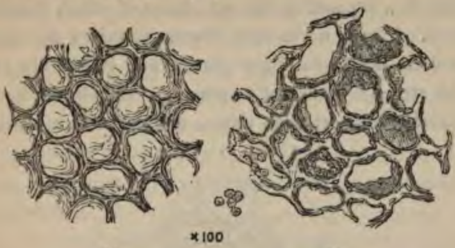

Fig. 18.—Section of cortical portion of a healthy kidney washed in water and examined in the same medium. The capillaries are not injected, and, being collapsed and shrunken, exhibit the fibrous appearance which is considered to depend upon the matrix.

Fig. 19.—Section of another part of the same kidney in which the vessels were injected. The nuclei on their coats are seen, but no fibrous matrix is distinguishable.

The so-called matrix described and delineated by Goodsir, Kölliker, Dr. G. Johnson, and others, I have not succeeded in demonstrating to my satisfaction; for, when the capillaries of the kidney have been distended with transparent injection, I have failed to demonstrate any fibrous structure between the wall of the tube and that of the vessels. The appearance considered to be fibrous matrix is easily seen in any thin section which has been washed and examined in water; but in such a section it is impossible to distinguish the walls of the tubes, those of the capillaries, and the so-called fibrous matrix, from each other. It has been figured by many as a distinct structure; and Fig. 18, representing a section which has been washed in water, gives the appearance most distinctly. Fig. 19 represents an injected specimen from the same kidney, which does not exhibit any indication of fibrous tissue existing between the vessels and the tubes. Here and elsewhere, as I have shown, the stretched and crumpled capillaries produce an appearance resembling fibrous tissue or matrix of the kidney (*Archives of Medicine*, No. III, 1858).

This so-called matrix has been compared to the ultimate ramifications of Glisson's capsule; and it has been considered necessary as a support to the structures of which the gland is composed. I have never seen fibrous tissue in the situation described in health in either gland; and it is quite obvious that the structures do not require any supporting tissue, as they mutually support each other; and any matrix would tend

Fig. 20.—Thin section of healthy human kidney slightly washed in water. *a*. Convoluted portion of uriniferous tube. *b*. A portion of a tube stripped of its epithelium. *c*. Outline of tube and crumpled capillaries, having a fibrous appearance—the so-called matrix. *d*. Very small Malpighian body. Loops of vessels shrunk, showing cells in thin walls. × 215.

to increase the distance between the secreting cells and the blood, while we certainly find in these organs every arrangement to reduce this as far as possible consistently with strength. If this matrix exists, it ought to be developed as a structure distinct from the tubes and vessels; but, as far as I know, it has not been demonstrated in the embryo at an early stage of

development of the kidney, by any one; and, in a careful examination of embryonic structures, one cannot fail to be struck with the absence of this fibrous tissue, which is by some regarded as an essential part of every organ. The morbid changes are surely explained as well by supposing the effusion of a new material between the walls of the tubes and those of the vessels, and by a thickening or other change in one or both of these structures, as by attributing them to an alteration in the matrix or intertubular areolar or fibrous tissue (*Bindegewebe*).

The conclusions to which I have arrived, from numerous investigations on this subject, may be summed up as follows:—

1. In the cortical portion of the kidney there is no evidence of the existence of a "*fibro-cellular matrix*".

2. The fibrous appearance observed in thin sections of the kidney which have been immersed in water is due to a crumpled, creased, and collapsed state of the membranous walls of the secreting tubes and capillary vessels.

3. A small quantity of a transparent and faintly granular material, with distinct nuclei, the nature of which has not yet been determined, is to be demonstrated between the walls of the tubes and the capillary vessels.

4. The changes met with in disease can be fully explained without supposing the existence of a *fibrous matrix*.

On some Points connected with the Physiology of the Kidney. The course of the blood has been fully described, and it has been shown how eminently adapted the Malpighian tuft is to facilitate the free escape of the watery parts of the blood. The influence of the nervous system upon the secretion of urine is well known. Nerves may be traced upon the large arteries, and followed on the small vessels for a considerable distance. I have seen nerves upon the Malpighian arteries which may be traced up to the tuft. I have not succeeded in demonstrating nerves in connexion with the capillaries of the tuft; but a careful examination of several specimens has led me to con-

clude that these capillaries are supplied with nerves, as appears also to be the case with the capillaries of the ciliary processes of the eye, and some other capillary vessels. I am now investigating the mode of distribution of the nerves to vascular structures, and I hope soon to be able to express myself more definitely on these very interesting questions.

Fig. 21.—Capillary vessels from the Malpighian tuft of a human kidney which had been injected with dilute Prussian blue injection, showing nuclei connected with their walls. *a.* A few coils separated from the rest of the tuft. *b.* Part of a loop somewhat compressed, showing the nuclei a little flattened. *c.* Tissue which connects the coils with each other, and thus the globular form of the tuft is preserved, even when it is removed. *d.* A small portion of a capillary compressed as much as possible, showing the thickness of the capillary wall at the point of reduplication.

Virchow lays considerable stress on the existence of a collateral circulation through the vasa recta. He considers that the circulation in the medullary portion of the kidney is more free than it is in the cortex, because the blood in the latter region does not pass through Malpighian bodies. There can be no doubt of the correctness of Virchow's views upon this question, and I can confirm many of his statements from personal observation. Some time since, in examining some speci-

mens of diseased kidney, I was much struck with the thickness of the walls of some of the vasa recta in the pyramids. Upon further examination, these were found to exhibit the circular muscular fibres so characteristic of arterial walls. I have since carried out further investigations upon the healthy kidney, and *have found that many of the straight vessels running parallel with the tubes in the pyramids of the kidney are in reality small arterial branches with muscular walls.* These are supplied with nerve-fibres. I suspect that some of these branches communicate very readily with the veins in the same situation. This subject is one of very great interest, in connexion with the renal circulation.

In a state of health, the diminished rapidity of the circulation in the capillaries of the Malpighian body, consequent upon the greatly increased area of the capillaries which the blood must traverse as it flows from the small artery which alone supplies them, favours the transudation of water through the capillary walls. This fluid must at once pass into the uriniferous tube; and as it gradually traverses in succession the cells which line it, the soluble substances which they are at the same time separating are dissolved out—the quantity of solid constituents gradually increasing as the solution passes down the tube. Now, the blood just brought from the Malpighian body has parted with water, and is richer in urinary constituents than the blood in any other part of the kidney. This is conducted by the vessels into which the efferent vessel of the Malpighian body divides to the upper part of a uriniferous tube near the Malpighian body. We should expect that the cells in this region would be more fully charged with soluble urinary constituents than those lower down the tube; and, in accordance with this view, we find that these cells are acted upon by the almost pure water which has just escaped from the capillaries of the Malpighian bodies; while, by the time the fluid has reached the cells at a lower point of the tube, it is

already charged to a great extent with soluble constituents, and its solvent power is, of course, proportionately diminished.

Not the least important office of the cells lining the convoluted portion of the uriniferous tube is undoubtedly that of separating from the blood a considerable quantity of the *débris* of blood-corpuscles, in the form of extractive matters. It is possible that the cells may have the power of altering some of the substances they separate from the blood, and converting them into these peculiar urine extractives, the physiological importance of which, we may feel sure, must be very great, from the large amount which is excreted.

I have ventured to ask your attention to these minute anatomical points, because they seem to indicate conclusively the office performed respectively by the Malpighian body and by the epithelium of the uriniferous tube, as discovered by Bowman nearly twenty years ago. These views have lately been opposed by Dr. Isaacs in America, who tries to prove that the solid constituents are separated by an epithelium covering the capillaries of the Malpighian body (which, if it exists, is certainly very unlike glandular epithelium generally, and the cells must be very much smaller than he has represented); while, strange to say, he does not attempt to show what office is performed by that enormous extent of epithelial surface in the convoluted portion of the tube, or why the very peculiar relation between the extensive system of capillaries around the tubes and those of the Malpighian body exists. Bowman's views on the physiology of the kidney are supported by so many different facts, that they are now received by all who have carefully studied the subject from the different points of view which he has indicated.

On the Formation of Casts of the Uriniferous Tubes. Such, then, being the action of the kidney in health, let us consider briefly how this may become altered in certain cases. If the arterial walls were relaxed, more blood would pass into the Malpighian capillaries in a given time, and a great transuda-

tion of water would take place. If, on the other hand, the capillaries were contracted, the secretion of urine would be diminished accordingly. Many sudden and temporary alterations in the circulation of the blood through the Malpighian bodies of the kidney undoubtedly depend upon an influence exerted by the nervous system alone; but certain changes which are, unfortunately, of a more permanent character, are due to an altered action of the secreting cells. The rapidity of the circulation in the Malpighian body will be greatly influenced by the rate at which the blood traverses the capillaries around the uriniferous tubes; the flow of blood in these vessels being governed by the attractive force exerted by the cells within the tubes for the urinary constituents dissolved in the concentrated blood. Now if, from any cause, the action of the secreting cells became impaired, and they ceased for a time to exert their attraction for the constituents they ought to separate from the venous blood, a retardation to the circulation in these capillaries would result. This would affect backwards, as it were, the capillaries of the Malpighian tuft, in which the blood, urged on through the arteries, would tend to accumulate. Their thin walls, being much stretched, would not resist the passage of other constituents of the blood; albumen and extractive matters would pass into the tube, and escape in the urine. Supposing this state of things to go on, the pressure on the Malpighian capillaries must necessarily increase; and these capillaries, distended to their utmost, and their walls stretched to the last degree, would at length burst, and all the constituents of the blood, including the blood-corpuscles, would pass into the tube, and would escape with the urine. The density of the walls of the Malpighian capillaries, which permits the escape of water in health, will favour the escape of other constituents of the blood, and increase their chance of rupture in disease, if they be exposed to increased pressure; but the collateral circulation above referred to in some measure counteracts such a result.

Professor Virchow has lately arrived at the conclusion that albumen and other constituents of the blood more frequently escape from the straight vessels of the pyramids than from those of the Malpighian bodies. In the former case, the constituents of the blood would have to pass through the walls of the tubes, as well as through those of the capillaries; while surely, if this were the seat of the mischief, we ought to find an œdematous condition of the kidney, and blood effused between the tubes more frequently than is the case. It seems to me that, before such a lesion was possible, the Malpighian capillaries must have become much thickened and altered in structure. In many chronic cases, as has been shown by Dr. Johnson, the Malpighian arteries become enormously thickened; and I have often observed the capillaries of the Malpighian body in a like condition; so that the permeability of their walls must be very greatly diminished.

In many cases of congestion, and in inflammation of the kidney, a spontaneously coagulable material is effused into the tubes, and coagulates there, forming a *cast or mould of the tube*, which is gradually washed out by the fluid which is secreted behind it, and thus it finds its way into the urine, from which it may be easily separated for examination.

Casts. A cast is composed of a coagulable material which is effused into the uriniferous tube; and, becoming solid there, it entangles in its meshes any structures which may be in the tube at the time, and forms a mould of the uriniferous tube. The characters vary very much in different cases, according to the state of the tubes and the part in which the effusion of the matter takes place. Various substances are often entangled in the cast; and, by observing the character of these, we are often enabled to ascertain the nature of morbid changes going on in tubes at the time the cast was being formed. Great difference of opinion has been expressed with reference to the nature of the material of which the cast is composed. By some it has been termed fibrine; but the striated appearance always present

in coagula of this substance is not found in the cast. Others have considered the cast was composed of albumen; but it is not rendered opaque by means of those reagents which produce precipitates in albuminous solutions. Not more than five years since, it was stated by two observers in France and Germany of high reputation, at least in other branches of scientific inquiry, that the cast really consisted of the basement membrane of the uriniferous tube. How such a statement could be made by any one possessing even a slight knowledge of the anatomy of tissues, it is difficult to conceive.

The transparent material probably consists of a peculiar modification of an albuminous matter possessing somewhat the same characters as the walls of some epithelial cells, the elastic laminæ of the cornea, the walls of hydatid cysts, etc. I think it not improbable that these casts of the uriniferous tubes may really be composed of the material which, in health, becomes converted into epithelial cells. In disease, this substance, perhaps somewhat altered, passes into the uriniferous tubes, and coagulates there. If this be so, the formation of the cast must result from depraved nutrition, and the material must pass into the tube from the intertubular capillaries—an idea which receives some support from the fact that occasionally casts are formed although no albumen passes into the urine. According to this notion, it is possible that a cast might be formed quite independently of any congestion or morbid condition of the Malpighian tuft; but, as a general rule, there can be no doubt that serum escapes as well as the coagulable matter, and albumen is found in the urine.

The diameter and general character of the cast will be determined by the state of the uriniferous tube at the time of its formation, as the researches of Dr. Johnson have indisputably proved. If the epithelium be abnormally adherent, the cast will be very narrow; if, on the other hand, the epithelium be removed, it will be of the width of the tube. Should the epithelium be disintegrating, the cast will afford evidence of the

change. If in a state of fatty degeneration, fat-cells will be entangled in it. In hæmorrhage from any part of the secreting structure, blood-corpuscles are present; and, when suppuration occurs, the cast contains pus-corpuscles. When the transudation of the coagulable material occurs in a tube to which the epithelium is intimately adherent, or in a tube whose walls are smooth, the cast will be clear and perfectly transparent. The import of all these different characters is fully discussed in the works of Dr. Johnson; and several interesting cases, under observation for a considerable period of time, will be found reported in Dr. Basham's work.

When discussing the different urinary deposits, we shall have to consider those forms of casts which are most frequently met with.

Professor Virchow thinks that casts are very constantly, if not entirely, formed in the straight portion of the uriniferous tubes; but you will, I think, feel satisfied that many of the facts we have been considering strongly militate against this idea. In morbid specimens, it is very common to see the casts in the tubes of the cortex. Moreover, as I have demonstrated

Fig. 22.—Casts of the uriniferous tubes from a case of acute suppurative nephritis. Casts found in the convoluted part of the tube are seen imbedded in material which has coagulated in the straight portion. Magnified 50 diameters.

in several cases, the cast receives successive layers upon its outer surface, as it passes down the tube (*Illustrations*, Plates XIV and XVI). In Fig. 22, portions of casts from the convoluted por-

tion of the tubes are seen imbedded in transparent material, which has undoubtedly coagulated in the straight part of the tube. We may, therefore, conclude that much may be learned with regard to the nature of the morbid changes going on in the secreting part of the uriniferous tube by a careful examination of the characters of the cast, as there can be no doubt that casts are generally formed in the convoluted portion of the tube, although, in certain cases, the coagulable matter may be effused in the straight portion also, in which case the diameter of the cast will be very much greater.

Circumstances under which the Urine may be altered in Quantity or Quality. In the remarks I am about to make, I shall consider it as proved that the solid constituents of the urine are separated by the cells lining the uriniferous tubes, while the water filters through the walls of the capillaries of the Malpighian body. Albumen and extractives may escape from the latter capillaries, and also from those surrounding the tubes. The material of which casts are formed probably enters through the walls of the tube, but it may also pass into the tube from the Malpighian body. Diuretics may act in two ways—1. By causing increased transudation of fluid from the Malpighian tuft, in which case pale urine, containing very little solid matter, will escape in considerable quantity; 2. By stimulating the cells to separate from the blood a larger amount of solid material, in which case a highly concentrated urine, rich in solid matter, will be secreted in greater proportion than in health. If the action of the cells be interfered with in any way, congestion of the capillaries around the tubes will occur; hence those of the Malpighian body will be distended, and albumen will probably pass into the tubes. In certain diseases, there seems to be a tendency on the part of the kidneys to throw off morbid material which exists in the blood. If, under these circumstances, the flow of blood to the kidneys is not compensated for by rapid removal of these

matters, congestion, perhaps running on to inflammation, occurs, and there is danger of serious damage to the organ.

It is in this manner that the albuminuria following scarlatina, and that coming on from exposure to cold, are to be explained. This subject has received full consideration from Dr. Johnson, in his work *On Diseases of the Kidney*, and also in that *On Cholera*. The action of many irritating diuretics is to be explained in a similar manner. A quantity of cantharides, which would do no harm to a strong healthy man with sound kidneys, would produce dangerous congestion and inflammation, with rupture of the capillaries of the Malpighian body, in a person who was recovering from an illness, or in one whose kidneys were affected by disease. In the one case, the secreting power of the cells appears increased by the action of the drug; while in the other they are incapable of effecting the increased amount of work suddenly thrown upon them, and the results above described must occur. Kramer and Golding Bird state that squill, copaiba, broom, juniper, and guiacum, cause the removal of an increased proportion of water from the blood, but do not influence the quantity of solid matter removed from the body in twenty-four hours. It seems probable that these remedies affect the capillaries of the Malpighian tuft, either directly, or through their action upon the nerves distributed to the renal vessels.

In cases where the blood is very watery, the excess of fluid is carried off by the kidneys; but, at the same time, a greater amount of solid matter is removed in a given time, partly arising from the tissues being washed out by the large quantity of fluid, and partly because the formation of urea, etc., is favoured by a dilute state of the fluids.

Many neutral salts (nitrates, sulphates, etc.) seem to increase the secretion of urine by being attracted from the blood in a state of solution, in all probability by the renal epithelium, the kidney being the channel by which they naturally leave the system. Urea has a similar diuretic action. Within certain

limits, the greater the quantity of these substances in the blood, the more will be removed by the renal epithelium, supposing this to be healthy. The more strongly the epithelial cells be charged with urinary constituents, the greater the quantity of water required to dissolve them out. This seems to be effected as follows :—When the urinary constituents are not removed from the cells by the water coming down from the tuft as fast as they are separated from the blood, they must accumulate until the surcharged cell ceases to exert that attractive force upon the blood in the capillaries around the tube which it does ordinarily. The tendency to stasis in the circulation thus caused necessarily interferes with the free passage of the blood through the Malpighian capillaries, and the increased pressure which results causes the escape of fluid into the tube, which washes out the solid matter accumulated in the cells. The latter resume their action, the circulation becomes free again, and the normal relation between the action of the cells of the tube and the Malpighian body is reestablished.

Now alkalies, and especially the citrates, tartrates, and acetates, which become converted into carbonates in the system, increase not only the quantity of water removed from the system, but also materially augment the proportion of solid matter. These salts increase the quantity of urea and other matters formed. They seem to favour the conversion of the products resulting from the disintegration of tissue into these constituents. The action of such remedies is very desirable in a vast number of cases; and where the kidneys are healthy, they invariably act favourably. The renal epithelium is intimately concerned in the separation of the carbonates formed from these salts in the system, and the urinary constituents whose formation has been promoted by their presence.

A certain degree of dilution is necessary to ensure the diuretic action of many neutral salts. If the density of the solution be very great, exosmose of fluid from the blood will

take place; and certain salts may be made to act as purgatives or diuretics, according as they are diluted with a small or with a large quantity of water. The observations of Dr. Headland, however, show that this physical explanation cannot be applied in all cases. That sulphate of magnesia is absorbed, at least in the majority of instances, there can be no doubt. It is often excreted in large quantity in the urine; and it is probable, as Dr. Headland suggests, that its purgative action is due to its removal, in the form of a weak solution, from the blood by the action of the intestinal mucous membrane.

The excretion of urine will also be materially affected by all those circumstances which influence the circulation in the kidney. The compensating action existing between the cutaneous secretory surface and the kidneys has been already alluded to. Pressure on the renal arteries, or on the aorta above their origin, will diminish the secretion of urine. Pressure on the veins, on the other hand, will first of all cause an increased flow of urine, and afterwards albumen will escape. In congestion of the liver and portal system, the amount of solids is greatly increased. It would appear that in many cases, where the action of the liver is imperfect, and especially in some forms of organic disease, the kidneys to some extent perform the functions of the liver. In jaundice, both colouring matter and biliary acids are carried off in the urine. In this case, however, it must be borne in mind that these biliary constituents are formed by the liver, reabsorbed into the blood, and separated from it, as are many other substances abnormally present, by the kidney. In many affections of the liver, the urine-pigment is much increased; and it is probable that a certain proportion of material which, in a state of health, would have been converted into bile, is transformed into certain extractive matters and other substances, and eliminated in the urine. The crisis of many acute diseases is characterised by the presence of a large quantity of solid matter in the urine, and increased action of the kidney. Free sweating, and the

secretion of a urine containing a large amount of urea and urates, in the course of many diseases, are often the earliest and most important indications of approaching convalescence. Dr. Golding Bird showed that abatement in the severity of the symptoms of ague was always associated with an increase in the amount of solid matter in the urine. Now, in all these cases, it is obvious that the activity of the secerning power of the renal epithelium is increased, and that the separation of urinary constituents from the blood cannot be regarded as a mere percolation, but dependent upon a vital property of the cells; while an alteration in the proportion of the water is rather to be attributed to altered states of the calibre of the arteries which supply the Malpighian bodies, and to the variable pressure exerted by the blood as it traverses the Malpighian capillaries, depending to some extent upon the freedom with which it passes onwards into the capillary system, among the meshes of which the tubes lie.

On the Absorption of Substances at the Stomach, and their Excretion in the Urine. The rapidity with which weak solutions are absorbed from the digestive organs, and secreted by the kidney, is marvellous. In Mr. Erichsen's well known experiments, it was shown that ferrocyanide of potassium could be detected in the urine within a minute after it had entered the empty stomach. These interesting conclusions were derived from experiments made on a case in which, from the deficiency of the anterior wall of the bladder and abdomen, the orifice of the ureters could be seen, and the urine collected as it trickled from them. A German suffering from this terrible malformation was in London two years ago, and I think many of you had an opportunity of seeing him, and observing how very soon after a large quantity of water had been swallowed, the rate of the flow of urine from the ureters increased.

Anything interfering with the absorption of fluid from the stomach or intestinal canal will necessarily affect the secretion of urine. In various cases where the contents of the alimentary

canal are in a condition unfavourable for absorption, but a very small quantity of urine is formed. Dr. Barlow has gone so far as to say that the seat of an obstruction in the intestine can be ascertained by noticing the quantity of water excreted in the form of urine. When close to the pylorus, it is stated that scarcely any urine is separated. In ordinary cases of what is known as sick headache, where, from temporary stomach derangement, little absorption occurs for some hours, no urine is secreted perhaps for twelve hours or longer. The termination of the attack is marked by the very free and rapid action of the kidneys.

Morbid Changes affecting the Structure of the Kidney. In cases where the blood which passes through the kidney is unhealthy, and especially when it is loaded with noxious matter, as takes place in the majority of cases of long continued beer or spirit drinking, the secreting power of the renal cells is gradually impaired. They lose their healthy appearance, and become much shrivelled, and at last suffer disintegration; while, in consequence of the germs having been destroyed at an early period of growth, their place is not occupied by a new generation. A complicated series of morbid changes in other structures of the kidney gradually ensues; and, in consequence of the blood being rendered still more depraved by the accumulation in it of matters which ought to be removed by the kidney, other organs are gradually involved.

In the kidney, it will be observed that the coats of the smaller arteries become much thickened, the capillaries shrink, while their walls become thicker and often granular. The quantity of blood distributed to the organ diminishes; and many of the capillaries, being no longer required, shrink and cease to transmit blood. The diameter of the secreting tubes decreases, while the basement membrane is thickened and more impervious. The whole organ becomes hard, and at the same time small and shrunken. This decrease in size takes place principally at the expense of the cortical or secreting portion of the

kidney, as would be supposed. Such serious changes in the structure of an organ so important as the kidney necessarily affect the system generally, but these we must not now stop to consider. The Malpighian bodies also waste. The remains of many may be seen without a capillary in them being pervious; and not a few of those which still exist are found to be so altered that they can hardly be recognised as Malpighian bodies at all. The greater part of the blood sent to the kidney passes into the pyramids by the *vasa recta*, and soon reenters the veins, a small quantity being distributed to those tubes and Malpighian bodies nearest the pyramids. The diminished amount of urea, etc., present in the urine, is probably separated in this latter situation; while a certain quantity of water, with a little albumen and the material of which the casts are formed, also escape in this situation, as well as from the straight part of the tubes.

Long before the disease has arrived at this stage, the urine will be found to contain a very small amount of solid matter, which consists principally of salts and extractives, with a very little urea.

By many pathologists these changes are explained by the effusion of inflammatory lymph, and subsequent thickening, condensation, and contraction of the so-called *matrix;* but it seems to me that all the appearances observed may be much more simply accounted for on the view that they depend upon depraved nutrition and wasting, than by resorting to the hypothesis of the inflammation of a structure whose existence has not been satisfactorily demonstrated, and which, if it does exist, according to its warmest advocates, only serves as a supporting tissue to the more essential elements of the gland-structure. It is very hard to see why such a tissue, which takes no active part in the changes going on in the gland, should be the starting-point of all the serious morbid alterations which occur. The idea, I believe, has arisen from a supposed analogy between cirrhosis of the liver and the so-called chronic inflam-

matory disease of the kidney. Cirrhosis was considered to depend upon inflammation, thickening, and subsequent contraction of another supporting fibrous tissue (Glisson's capsule), which was supposed to surround the lobules of the liver, and by its contraction to press upon the vessels ("On Cirrhosis of the Liver," *Archives of Medicine*, vol. i, p. 118). For the origin of these morbid changes, we must look to the altered actions going on in the secreting structure, and not to inflammations of tissues of doubtful existence, which take no part in the nutritive operations or gland-functions. The conclusions to which I have arrived from my own observations, with reference to the nature of the so-called matrix in the healthy kidney, and the changes taking place in disease, are at variance with those usually entertained both in this country and on the continent. The discussion of this question involves the whole subject of areolar tissue and its corpuscles, and I therefore propose to defer it until this has been fully entered into in another place. For an admirable statement of the opinions generally held, with many original observations, I must refer you to a work by Arnold Beer, just published in Berlin (*Die Binde-Substanz der Menschlichen Niere*). The drawings accompanying this work appear to me rather rough. The engraver perhaps has misinterpreted some of the author's representations.

In other cases, the epithelium undergoes a very peculiar change, to which much attention has been given of late years. Fatty matter accumulates in the cells of the uriniferous tubes. The intertubular capillaries and those of the Malpighian bodies are also affected in a similar manner, and little collections of minute oil-globules may often be seen at intervals in their walls. This change often commences in a few of the tubes, and gradually extends until the whole organ is affected. The kidney is in many instances much enlarged, while its colour has become very pale. Fatty degeneration, in many cases, is not confined to a single tissue or organ, but almost every part of the body is more or less involved.

Bright's Disease. This term has been applied to all *morbid conditions of the kidney associated with albuminous urine.* Of late years many important characters have been made out, by which we are enabled to distinguish several diseases of the kidney essentially different from each other—different in their origin, in their progress, and often in the results to which they lead. Dr. Johnson has accurately described several of these morbid changes, and his researches have been confirmed by other pathologists. However, some physicians still insist that the different conditions above alluded to are merely different stages of one and the same morbid process. Let me ask you to examine carefully the small contracted kidney so commonly found in the bodies of old drunkards, with its rough puckered surface and diminished cortical portion, and contrast it with the large, smooth, and pale kidney, in a state of fatty degeneration, which is not unfrequently met with in young people not more than twenty years of age. The causes of these diseases are different; the conditions under which they occur are different; and, although the result is fatal in both, death occurs in a very different way. Their chemical characters are different; their microscopical characters indicate the occurrence of changes which are totally distinct. Again, the treatment required in the early stages of these diseases, when alone any benefit is likely to be derived from treatment, is different.

The divisions and nomenclature adopted by Dr. Johnson are the following: *Acute desquamative nephritis; Chronic desquamative nephritis; Waxy degeneration of the kidney; Non-desquamative disease of the kidney; Fatty degeneration of the kidney; Suppurative nephritis.* Dr. Johnson still supports the same classification, and opposes the theory held by some pathologists with reference to the *oneness* of Bright's disease. He has recently written a paper on this subject, which will be found in vol. xlii of the *Medico-Chirurgical Transactions.* Dr. Johnson says, with regard to the oft debated question if large kidneys, at a subsequent stage of the morbid changes, contract, "The *rule*

is, that a large Bright's kidney remains large to the end, and does not become a small one; and, on the other hand, a contracted Bright's kidney does not pass through a previous stage of enlargement."

We come now to the consideration of the nature of the various substances found in an insoluble condition in various morbid specimens of urine. Under this head I shall include insoluble substances floating upon the surface or suspended through the fluid, and those which, from their tendency to subside after the urine has been allowed to stand for some time, are properly termed *urinary deposits*. In the next lecture, I shall describe the methods of collecting and preserving urinary deposits, and draw your attention to the nature of various substances of extraneous origin which are often accidentally present in urine, and are not always easily recognised, leading thereby to great confusion; and in some instances, the observer, ignorant of their characters, has fallen into the most ridiculous mistakes.

LECTURE VII.

URINE IN DISEASE. *Insoluble Substances in Urine.* 1. *Floating on the Surface, or suspended through the Fluid.* URINARY DEPOSITS. 2. *Light and Flocculent Deposits.* 3. *Dense and Opaque Deposits.* 4. *Granular and Crystalline Deposits.* EXAMINATION AND PRESERVATION OF URINARY DEPOSITS. *Collecting Urine for Microscopical Examination. Period when the Urine should be examined. Removal of the Deposit from the Vessel containing it. Of Collecting a very small quantity of a Deposit from a Fluid. Magnifying Powers required in the Examination of Urine. Of the Chemical Examination of Urinary Deposits. Examination of the Deposit in the Microscope. Of Placing the Deposit in the Preservative Fluid. Refractive Power of the Medium in which Deposits are mounted. Media in which Urinary Deposits may be preserved. Of Keeping the Deposit for subsequent Inquiries. Of Preserving Deposits permanently. Mucus, Epithelium, Fungi, and Vegetable Growths. Spermatozoa. Casts. Pus. Phosphates, Urates, Blood-Corpuscles, Uric Acid, Cystine, Oxalate of Lime. On Preserving Crystalline Substances which are more or less Soluble in Water.* OF EXTRANEOUS MATTERS OF ACCIDENTAL PRESENCE. *Larvæ of the Blow-fly. Hair. Cotton and Flax Fibres. Portions of Feathers. Silk. Fibres of Deal from the Floor. Starch-Granules. Portions of Tea-Leaves. Milk. Sputum. Epithelium from the Mouth. Vomit.*

GENTLEMEN,—We now come to the examination of the different insoluble substances which are often met with in the urine in cases of disease. You may remember that I mentioned that in healthy urine only a very little insoluble material, in the form of a faint flocculent cloud, was to be detected. This consists of granular matter, probably composed of epithelial *débris*, and imperfectly formed cells of epithelium derived from some part of the genito-urinary mucous membrane. This is

what is ordinarily termed the *mucus* present in healthy urine, and may be greatly increased in quantity in certain diseases of the mucous membrane.

It will be convenient, for the purposes of description, to arrange these insoluble substances in a certain order; and I think that the subdivision which I shall recommend to your notice will be found of some practical value when you are trying to discover the nature of different insoluble substances. It is not my endeavour to devise a natural classification, but merely to arrange deposits in the order in which they can be practically treated of most conveniently. There are objections to this, as to every other subdivision; but, as it is simple, and depends merely upon the general characters which you can observe by the unaided eye, I venture to recommend it to you.

Insoluble substances may float on the surface of the urine, or may be diffused throughout the fluid, or they may sink to the bottom, forming *deposits* of greater or less density.

1. *Insoluble Matter floating upon the Surface of Urine, or diffused through the Fluid.* Fatty matter in a very minute state of division, as it occurs in cases of *chylous urine*, is one of the most important substances contained under this head; and, in alluding to this form of fatty matter, it will be convenient to direct your attention at the same time to all the different states in which fatty matter is found in the secretion, *dissolved by* other constituents; in a *molecular* or *minutely divided state;* in the form of *globules*, which may be *free*, contained in *casts*, or within *cells* constituting fat-cells; or in the form of small *concretions*, as described under the term *urostealith* by Heller, but only in one single case.

Urate of soda is another substance which is often suspended in a molecular state through the fluid, rendering it turbid; but this also forms a deposit, and it will therefore be more convenient to consider it under that head. Phosphates are found not unfrequently in the pellicle upon the surface of urine; but in

this case they are merely buoyed up, as it were. We shall have to consider this salt also under urinary deposits.

2. *Light and flocculent Deposits, usually transparent, and occupying considerable volume.* Under this head I shall include mucus, with different forms of epithelium derived from the kidney, ureter, bladder, urethra, vagina, etc.; certain well defined forms of fungi and vibriones; sarcinæ; spermatozoa; casts of the uriniferous tubes; rarely, benzoic acid in small quantity.

3. *Dense and opaque Deposits, occupying considerable bulk.* This class includes only deposits of urates, pus, and phosphates.

4. *Granular or crystalline Deposits,* occupying a small bulk, sinking to the bottom, or deposited upon the sides of the vessel. This division includes a great many different substances. Among the most important are uric acid, oxalate of lime, certain forms of triple phosphate and phosphate of lime, cystine, carbonate of lime, blood-corpuscles, and very rarely, cancer-cells, tubercle-corpuscles, and echinococci.

Examination of Urinary Deposits.

The examination of urinary deposits is now a subject of such great importance, and the advantages derived from it are so generally admitted, that I need scarcely refer to its value, in assisting us to form a diagnosis in many cases of disease. Within the last fifteen or twenty years, the investigation of urinary deposits has been so much simplified by the conjoint use of the microscope and chemical analysis, that the nature of the greater number of deposits has been correctly ascertained. When you commence examinations of urinary deposits for the first time, you will doubtless meet with many difficulties; and in some specimens which you examine you will perhaps discover no deposit whatever; whilst in examining others, the whole field of the microscope is seen to be occupied by substances of various shapes and colours, the nature of which you will be unable to ascertain. Many of the substances which

lead to this difficulty have obtained entrance into the urine accidentally; and I must therefore warn you against mistakes easily made, which are serious, and may bring great discredit upon your powers of observation. Portions of hair have been mistaken for casts of the renal tubes; starch-granules for cells; and other substances of extraneous origin, such as small portions of woody fibre, pieces of feathers, wool, cotton, etc., often take the form of some of the urinary deposits, and to a certain extent resemble the drawings given of them in their general appearance, so as to mislead the student in his inferences, and retard his progress in investigation.

Collecting Urine for Microscopical Examination. Urine, which is to be submitted to examination, should be collected in considerable quantity, in order to obtain sufficient of the *deposit* for examination. In many instances, the amount of sediment, even from a pint of urine, is so small that, without great care in collecting, it may be altogether passed over. The amount of deposit from a measured quantity of urine should always be roughly noted. The space occupied by the deposit may be compared with the total bulk of the fluid, and we may say the deposit occupies a fifth, a fourth, half the bulk of the urine, etc.

Bottles used for carrying specimens of urine should be made of white glass, with tolerably wide mouths, and capable of holding at least four ounces; but, if the sediment only of the urine is required, the clear supernatant fluid may be poured off, after the urine has been allowed to stand for several hours, and the remaining deposit may then be poured into small bottles of an ounce capacity, or even less. The only objection to this latter mode of collecting urine is, that no estimate of the *amount* of sediment deposited by a given quantity of urine can be formed. The bottles may be arranged in a case capable of containing two, four, or six. They may be obtained of Messrs. Weiss, in the Strand; Mr. Matthews, near King's College Hospital; and other instrument makers.

Period when the Urine should be Examined. In all cases the urine should, if possible, be examined within a few hours after its secretion; and, in many instances, it is important to institute a second examination after it has been allowed to stand for twenty-four hours or longer. Some specimens of urine pass into decomposition within a very short time after they have escaped from the bladder; or the urine may even be drawn from the bladder actually decomposed. Under these circumstances, we should expect to find the secretion highly alkaline, having a strongly ammoniacal odour, and containing crystals of triple phosphate, with granules of earthy phosphate; and upon carefully focussing, numerous vibriones may generally be observed. In other instances, the urine does not appear to undergo decomposition for a considerable period, and may be found clear, and without any deposit, even for weeks after it has been passed.

In those cases in which *uric acid* or *oxalate of lime* are present, you will find that the deposit increases in quantity after the urine has stood for some time. These salts are frequently not discoverable in urine immediately after it is passed, but make their appearance in the course of a few hours. The deposition of uric acid depends upon a kind of acid fermentation, which has been the subject of some beautiful investigations by Scherer.

In order to obtain sufficient of the deposit from a specimen of urine for microscopical examination, we must place a certain quantity of the fluid in a conical glass (page 3); in which it must be permitted to remain for a sufficient time to allow the deposit to subside into the lower part.

Removal of the Deposit from the Vessel containing it. In order to remove the deposit from the lower part of the vessel in which it has subsided, I firmly close the upper end of the pipette with the forefinger, the tube being held by the thumb and middle finger. Next, I plunge the lower extremity down to the bottom of the deposit. The forefinger may now be raised

very slightly, but not completely removed, and a few drops of the fluid with the deposit slowly pass up into the tube. When a sufficient quantity for examination has entered, I press the forefinger again firmly upon the upper opening, and carefully remove the pipette. A certain quantity of the deposit is now allowed to flow from the pipette on to the glass-slide or cell, by gently raising the forefinger from the top. It is then covered with the thin glass cover, and subjected to examination in the usual way. Dr. Venables recommends that the deposit should be obtained by inverting a corked tube into which the urine has been previously poured. A small quantity of the deposit adheres to the cork, and may be removed to a glass-slide; but, as a general rule, I think the plan above described will be found efficient.

Of Collecting a very small quantity of a Deposit from a Fluid. When the quantity of deposit is very small, the following plan will be found of practical utility. After allowing the lower part of the fluid which has been standing to flow into the pipette, as above described, and removing it in the usual manner, the finger is applied to the opening, in order to prevent the escape of fluid when the upper orifice is opened by the removal of the finger. The upper opening is then carefully closed with a piece of cork. Upon now removing the finger from the lower orifice, the fluid will not run out. A glass-slide is placed under the pipette, which is allowed to rest upon it for a short time. It may be suspended with a piece of string, or supported by the little retort stand. Any traces of deposit will subside to the lower part of the fluid, and must of necessity be collected in a small drop upon the glass-slide, which may be removed and examined in the usual way.

Another plan is to place the fluid, with the deposit removed by the pipette, in a narrow tube, closed at one end, the bore of which is rather less than a quarter of an inch in diameter. This may be inverted on a glass-slide, and kept in this position with a broad elastic India-rubber band. The deposit, with

a drop or two of fluid, will fall upon the slide, but the escape of a further quantity of fluid is prevented by the nature of the arrangement.

Magnifying Powers required in the Examination of the Urine. Urinary deposits often require to be examined with different magnifying powers; those which are most frequently used being the inch and the quarter of an inch. The former magnifies about 40 diameters ($\times 40$); the latter from 200 to 220 ($\times 200$, $\times 220$). Large crystals of uric acid are often readily distinguished by the former, but crystals of this substance are sometimes so minute that it is absolutely necessary to use high powers. Octohedra of oxalate of lime are frequently so small that they cannot be seen with any power lower than a quarter; and, in order to bring out the form of the crystals, even higher object-glasses than this are sometimes necessary. Spermatozoa may be seen with a quarter, but they then appear very minute. In these cases, an eighth of an inch object-glass, which magnifies about 400 diameters ($\times 400$), will be of advantage. The casts of the tubes, epithelium, and the great majority of urinary deposits, can, however, be very satisfactorily demonstrated with a quarter of an inch object-glass.

You will often learn much by subjecting a deposit, the nature of which is doubtful, to examination in various fluids, such as water, spirit, mucilage, turpentine, Canada balsam, etc.

Of the Chemical Examination of Urinary Deposits. In the investigation of those deposits which are prone to assume very various and widely different forms, such as uric acid, it will sometimes be necessary to apply some simple chemical tests, before the nature of the substance under examination can be positively ascertained.

Suppose, for instance, a deposit which is found, upon microscopical examination, not to possess any characteristic form, be suspected to consist of uric acid, or of an alkaline urate, we have only to add a drop of solution of potash, which would

dissolve it, and then excess of acetic acid, when the crystals of uric acid will be deposited after some time in their well known rhomboidal form ; or any other chemical tests which should be considered necessary may be applied.

When it is requisite to resort to chemical reagents, a drop of the test-solution is to be added to the deposit, which is placed in the cell, or upon the glass-slide. If necessary, heat may be applied to the slip of glass by a spirit-lamp, and, with a little practice, the student will soon be able to perform a qualitative analysis of a few drops of urine, or of a very small portion of a deposit.

Examination of the Deposit in the Microscope. The drop of urine with the deposit is to be placed in a thin glass cell, or in one of the animalcule-cages sold by Messrs. Powell and Lealand, of the Euston Road. The latter instrument will be found convenient for examining urinary deposits, as a stratum of fluid of any degree of thickness can be very readily obtained.

Various parts of the specimen are to be brought into the field of the microscope. It is better to examine the object as regularly as possible, commencing on one side, and moving it up and down, until the whole has been traversed. After one specimen has been examined, and the nature of its contents noted, another may be treated in a similar manner. Specimens should be taken from the deposit at different levels, for while some deposits soon sink to the bottom, others are buoyed up, as it were, either by the small quantity of mucus which the urine contains, as is the case with small crystals of oxalate of lime, or by the flocculent nature of the deposit itself.

As each part of the deposit is brought under the field of the microscope, you should endeavour to recognise every object as it passes under view. This, however, will for some time be found a matter of considerable difficulty, arising partly from the great number of deposits which commonly occur together, and partly from the very various forms which many of these

substances are liable to assume, but chiefly, I believe, from the great number of substances of accidental presence which are found in almost every specimen of urine subjected to examination; especially in urine obtained from the wards of a hospital, upon which the first microscopical observations are usually made.

On the Preservation of Urinary Deposits as Permanent Microscopic Objects.

A desire has been generally expressed that a series of the most important urinary deposits should be kept for sale, so that practitioners might have an opportunity of readily obtaining named specimens, with which the deposits that from time to time fall under notice might be compared, and their nature recognised. Persons who prepare and sell microscopic objects have experienced great difficulty in preserving urinary deposits satisfactorily; and many specimens which have been purchased have been found to lose their characters after a few months, and have soon become quite useless objects. Feeling strongly the real practical value of preparations of this kind, it seems to me very desirable that a few rules with regard to the preservation of urinary deposits should be laid down; and I therefore propose to allude briefly to the different plans which I have found to succeed best. I hope that, shortly, there will be no difficulty in obtaining series of well-mounted and illustrative specimens.* At the same time, any one attending hospital practice, who has a little time at his disposal, can, without much trouble, prepare such preparations for himself.

The different characters of urinary deposits render necessary different plans of preservation. It is, therefore, desirable to consider the nature of the deposit before we attempt to preserve

* Specimens of urinary deposits may be obtained of Messrs. Smith and Beck, Coleman Street, City; Mr. Tennant, 149, Strand; and Mr. Matthews, surgical instrument maker, Carey Street, Lincoln's Inn Fields.

it. Some deposits may be preserved *dry*, others may be mounted in *Canada balsam*. A certain number exhibit their characters very well if preserved in *glycerine*, while many can only be kept in certain *aqueous fluids*.

Of placing the Deposit in the Preservative Fluid. After the deposit has been allowed to settle in a conical glass, the supernatant fluid is to be poured off; and if it is to be mounted *in fluid*, a quantity of the preservative solution, equal in bulk to the urine and deposit that remain, is to be added. After the deposit has again settled, the fluid is to be poured off and replaced with an equal portion of fresh preservative solution. In this way the deposit is washed clean, and properly impregnated with the preservative fluid.

When preparations are to be preserved in a fluid medium, a small shallow water-tight cell is to be used. The specimen and its preservative fluid being placed in the cell, the thin glass is applied, and the cover cemented in its place with the aid of Brunswick black or other cement. (*How to Work with the Microscope.*) In washing urinary deposits prior to mounting them, it is often necessary to add some compound to the water used for this purpose, in which they are known to be insoluble; and sometimes it is desirable to add some substance to increase the density of the fluid; for which purpose, certain salts, syrup, or glycerine, may be employed, according to circumstances. Many deposits, although soluble to some extent in pure water, are quite insoluble in a weak acid; others are insoluble in a weak alkali or in certain saline solutions. Again, it is sometimes desirable to separate certain substances in the deposit from others, and this may be effected by special chemical solutions which have the power of acting on the one and not upon the other; or, in cases where one is more dense than the other, by agitating the deposit with water, and, after allowing time for the heavier one to settle, pouring off the lighter one into another vessel, to subside there. From this, it may be collected in the usual way.

If the preparation is to be preserved as a *dry object*, water is to be added in the first place; and a portion of the deposit, which has thus been carefully washed, is to be removed with the aid of a pipette to the glass-slide, and the fluid allowed to evaporate, the whole being covered by a bell-jar, and placed over a dish of strong sulphuric acid. When dry, it is to be protected from dust by a thin glass cover. The glass cover is easily prevented from pressing upon the preparation by interposing a thin piece of paper or cardboard; or a thin India-rubber ring, which may be easily fixed to the glass-slide and thin glass cover, by a little gum made into a thick paste with whiting, may be used.

If the specimen is to be mounted in *Canada balsam* or turpentine, it is to be dried in the manner just described, warmed slightly, wetted with the balsam, and mounted with the usual precautions. (*How to Work with the Microscope.*)

Refractive Power of the Medium in which Deposits are Mounted. The appearance of objects in the microscope depends very much upon the medium in which they are immersed; and many structures are so altered in their character by different media, that they would hardly be recognised as the same object. It may be said generally, that the darker the object, and the more dense its structure, the higher should be the refractive power of the medium in which it is mounted—thus the dark coloured uric acid, or the thick spherical crystals of carbonate of lime, and the dumb-bells of oxalate of lime, exhibit their structure to the greatest advantage when mounted in the highly refracting *Canada balsam*, or in *strong syrup* or *glycerine*, while the beautifully transparent octohedra of oxalate of lime would be scarcely visible in these media, and require to be mounted in an aqueous fluid which possesses a lower degree of refractive power. Many of these objects, when mounted dry, appear quite dark, and scarcely exhibit any structure at all, in consequence of great difference in the refracting power of their substance, and the air by which they are sur-

rounded. From what I have said, it will be evident how important it is to examine the same object in different media—in fact, it is quite impossible to form an idea of the real structure of many specimens, without proceeding in this manner. (*How to Work with the Microscope*, p. 59; and *The Microscope in its Application to Practical Medicine*, second edition, sects. 74, 89, and 90.)

Media in which Urinary Deposits may be preserved. Urinary deposits may be mounted in *air*, in *turpentine*, *oil*, or *Canada balsam;* in *glycerine*, in *gelatine and glycerine*, in *solution of naphtha and creasote*, in *certain saline solutions*, in *weak spirit*, and in some other aqueous solutions, which will be alluded to. The "*glycerine*" which I use is *Price's patent glycerine*, diluted with water.

The composition of the naphtha and creasote fluid, above referred to, is as follows:—

Solution of Naphtha and Creasote.

Creasote	3 drachms.
Wood naphtha	6 ounces.
Distilled water	64 ounces.
Chalk, as much as may be necessary.	

Mix first the naphtha and creasote, then add as much prepared chalk as may be sufficient to form a smooth thick paste; afterwards add, very gradually, a small quantity of the water, which must be well mixed with the other ingredients in a mortar. Add two or three small lumps of camphor, and allow the mixture to stand in a lightly covered vessel for a fortnight or three weeks, with occasional stirring. The almost clear supernatant fluid may then be poured off and filtered, if necessary. It should be kept in well corked or stoppered bottles.

Of keeping the Urinary Deposit for subsequent inquiries. In cases where it is desirable to retain a certain quantity of the deposit in the preservative solution for subsequent examination, or for the purpose of making more preparations, it should

be kept in a small glass tube, with a tight fitting cork, and carefully labelled. Most urinary deposits may be kept for a longer time in this manner, than mounted in thin cells. I propose now to describe briefly the various plans adapted for the preservation of urinary deposits which I have found to succeed best.

First Class of Urinary Deposits.

Mucus. It is very difficult to preserve the character of the so-called "mucus corpuscles", or imperfectly formed epithelial cells, nuclei, and granules, which constitute the slight flocculent deposit met with in healthy urine, and termed "mucus". The naphtha and creasote solution is best adapted for the purpose, and it is desirable to place the specimen in a cell about the twentieth of an inch in depth.

Epithelium. The different varieties of epithelium are easily preserved, although, after the lapse of some time, minute oil globules make their appearance in them. They may be kept in naphtha and creasote fluid, to which one-fourth of its bulk of glycerine has been added. It is well to put up specimens of epithelium from the urethra, bladder, ureter, and pelvis of the kidney, removed from the organs of a healthy man who has been killed accidentally. They should be mounted in very thin cells. Specimens of the epithelium from the vagina, which can generally be obtained from the urine of females, should also be preserved.

Vegetable Growths: Fungi. I have found that fungi may be preserved most satisfactorily in glycerine, for although they appear somewhat more transparent in this fluid than in urine, they preserve their general character better than when immersed in other preservative fluids. It is necessary to add weak glycerine in the first instance, and to increase the strength gradually, otherwise the fungi become collapsed, owing to the great density of the strong solution. A solution composed of

equal parts of water and Price's glycerine is sufficiently strong to preserve fungi. I have not been able to preserve specimens of sarcinæ which I have met with on two or three occasions in the urine, probably in consequence of their extreme delicacy. The sarcinæ which are from time to time met with in vomit keep perfectly well, and preserve their recent characters in glycerine.

Spermatozoa are sometimes mounted in the dry way; but although their general form is preserved, their refractive power and transparent appearance are so different from what is observed when they are immersed in urine, that little is gained from such preparations. Spermatozoa keep very well in glycerine, although they appear rather more faint than in an aqueous fluid. They should be examined with the *eighth of an inch object-glass* ($\times$ about 400); but when the eye of the observer has become familiar with the general appearances, they may be readily recognised with a quarter of an inch object-glass ($\times$ about 200).

Casts. It is not difficult to preserve the character of some varieties of casts. The transparent casts often become covered with numerous minute granules and oil globules, and their character much altered. Granular casts and epithelial casts often keep very well in the naphtha and creasote solution; but altogether I prefer glycerine, with one-third part of water. Although in many instances the cells they contain are altered, and oil globules appear much more transparent than when in urine, this alteration in character may be easily allowed for. I have some specimens of large waxy casts and epithelial casts which have been kept in the naphtha and creasote solution for upwards of seven years, and still preserve their characters well. The specimens in glycerine, of course, keep admirably. Some casts may also be preserved in gelatine and glycerine, care being taken that the mixture is not made too hot.

Second Class of Urinary Deposits.

Pus. Recent specimens of pus may be so readily obtained that it is hardly necessary to attempt to preserve the corpuscles permanently. Their characters alter so much in all the preservative fluids that I have tried, that after they have been put up for some time, it would be difficult to recognise the nature of the preparation.*

Phosphates. The phosphate of lime, in its amorphous form, in globules, and minute dumb-bells, is easily preserved in weak spirit, naphtha and creasote fluid, or glycerine; but the character of the crystals of the triple or ammoniaco-magnesian phosphate, could not be retained in this solution. As is well known, this salt is quite insoluble in solutions of ammoniacal salts, and these make the best preservative solutions for it. Crystals of triple phosphate may be kept for any length of time, with their smooth surfaces and their lustre unimpaired, in distilled water, to which a little chloride of ammonium has been added. Phosphate of lime and the stellar form of triple phosphate may be dried carefully, and mounted in Canada balsam; but, of course, the appearance of the crystals is a good deal altered.

Urates. As the urates are so commonly met with, and as they are generally deposited in the form of granules, there is scarcely any need of mounting them as permanent objects. If desired, however, deposits of this kind may be preserved by adding a little naphtha and creasote fluid to the deposit, which should be left in it for a considerable time before it is put up. Urates which crystallise in small spherical masses, as often occur in the urine of children, and more rarely in irregularly branched processes, may be preserved very well in Canada

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* Dr. Andrew Clarke speaks highly of some fluids, containing bichloride of mercury and arsenious acid, which he has prepared. (*The Microscope in its Application to Practical Medicine*, second edition, p. 237, note.)

balsam, or, if preferred, they may be kept in the naphtha and creasote fluid.

Third Class of Urinary Deposits.

Blood Corpuscles become more or less altered in most preservative fluids. I think that those which I have mounted in glycerine (one part glycerine to two parts of water) have undergone the least change.

Uric Acid Crystals are easily preserved as permanent objects. The usual plan is to mount them in Canada balsam. They should be washed, in the first instance, with a little water, to which a few drops of acetic acid have been added. When pretty clean, they may be placed upon a glass slide, with the aid of a pipette, and the greater quantity of the fluid absorbed with a small piece of bibulous paper. After the crystals have been properly arranged on the slide with a needle, they may be dried, by exposure under a bell jar over a dish containing sulphuric acid. When quite dry, they may be moistened with a drop of turpentine, and mounted in Canada balsam. In this operation, a very slight heat should be employed, otherwise the crystals will become cracked in all directions, and more or less opaque. Uric acid crystals, as a general rule, do not keep well in glycerine. In cases where we wish to preserve other substances in the deposit as well as uric acid crystals, the naphtha and creasote fluid will be found to answer very well. I have some preparations mounted in this manner, which were put up six or seven years ago.

Cystine. Crystals of cystine may be preserved in Canada balsam, the same care being taken in mounting them as mentioned under uric acid, or they may be kept very well in distilled water, or in the naphtha and creasote fluid, to which a little acetic acid has been added.

Oxalate of Lime. Both the octohedra and dumb-bells may be preserved in glycerine; but the former look very transparent in that fluid. The dumb-bells may also be mounted in Canada

balsam, but in this medium the octohedra are almost invisible. When required for polarising, they should be put up in balsam. The dumb-bells keep very well in glycerine.

On Preserving Crystalline Compounds obtained from Urine. It is exceedingly difficult to preserve many of the crystalline substances obtained from urine in a moist state; but several of them form beautiful microscopic objects when carefully dried. *Urea, nitrate of urea, oxalate of urea, creatine, creatinine, alloxan, hippuric acid, murexid,* and many others, may be kept as permanent objects in this manner. In order to prepare them, it is better to cause them to crystallise upon a glass slide; allow the mother liquor to drain of, and immediately place the slide under a bell-jar over sulphuric acid. Sometimes the crystals may be made in a small evaporating basin, and when drained and dried, a portion of them may be removed to a glass cell, and covered with a piece of thin glass to exclude the dust. Many crystals may be examined and preserved for a considerable time in their own mother liquor, especially when they are very slightly soluble in fluid; but, as a general rule, this plan does not answer very satisfactorily, for, independently of the escape of the fluid from the edges of the cell, a few of the largest crystals grow still larger at the expense of the smaller ones, and the beauty of the specimen is destroyed. The different forms of these crystals, as they appear in the microscope, are given in the *Illustrations of Urine, Urinary Deposits, and Calculi.* (Urine, plates I to IX.) See also *The Microscope in its Application to Practical Medicine*, chapter ix, page 292.

OF EXTRANEOUS MATTERS.

In the microscopical examination of urinary deposits, the observer often meets with substances the nature and origin of which he cannot readily determine. This is due in many instances to the presence of bodies which have fallen in accidentally, or which have been placed in the urine for the express

purpose of deceiving the practitioner. The importance of recognising matters of an extraneous origin can scarcely be sufficiently dwelt upon, for until the eye becomes familiar with the characters of these substances, it will be obviously quite impossible to derive such information from a microscopical examination of the urine as will enable the observer to distinguish between those bodies whose presence denotes the existence of certain morbid conditions, and certain matters which have accidentally found access, and, clinically speaking, may therefore be entirely disregarded. Practitioners who use the microscope for investigating the nature of urinary deposits, will derive advantage from subjecting many of the substances referred to separately to microscopical examination, so that when met with in the urine, their nature may be at once recognised. As most of the undermentioned substances are readily obtained and easily subjected to examination, a brief notice of their character will be sufficient. Your attention should be especially directed to the fact of the frequent occurrence of many of these extraneous substances in urine, and you should particularly notice those characters in which they resemble any insoluble substance derived from the bladder or kidney, or deposited from the urine after it has been standing for some time.

The following are some of the most important of these extraneous matters which have fallen under my own notice:—

Human hair.	Milk.
Cats' hair.	Oily matter.
Blanket hair.	Potato starch.
Worsted.	Wheat starch.
Wool.	Rice starch.
Cotton and flax fibres.	Tea leaves.
Splinters of wood.	Bread crumbs.
Portions of feathers.	Chalk.
Fibres of silk.	Sand.

The microscopical appearances of these substances are given in Plates I, II, and III, figures 1 to 16, of the "*Illustrations*

of Urine, Urinary Deposits and Calculi." You would hardly believe what curious and unexpected substances are sometimes found in the urinary secretion. Some time since, a specimen of urine was sent for examination, which contained several white bodies, about half-an-inch in length, like maggots. Upon microscopical examination, I found that these contained tracheæ, and they ultimately proved to be *larvæ of the blowfly*, although it had been stoutly affirmed that they had been passed by the patient.

A few years ago, Dr. Stewart informed me that a man had brought some urine to him for examination with a thick, brick-red deposit, which was analysed by Mr. Taylor, and proved to consist of sesquioxide of iron. The urine containing this deposit was of specific gravity 1·011; and, upon the addition of ammonia, a brown flocculent precipitate (hydrated sesquioxide of iron) was thrown down. Dr. Stewart tells me, that a considerable quantity of the powder (jeweller's rouge, or sesquioxide of iron) remained suspended in the urine after it had stood for many hours, and that the fluid was still turbid after having been passed through a double filter. The man who brought this urine has been endeavouring for some time to impose upon different hospital physicians.

Hair of various kinds is very frequently found amongst urinary deposits, but, as its microscopical appearance is so well known, it is not necessary to enter into a description of the characters by which it may be distinguished. The varieties of hair most commonly found are human hair, blanket hair, and cat's hair. Not unfrequently portions of coloured worsted will be met with: but the colour alone will often remove any doubts with reference to the nature of the substance. Portions of human hair are sometimes liable to be mistaken for transparent casts of the uriniferous tubes, which are quite destitute of epithelium or granular matter, and which present throughout a homogeneous appearance. The central canal, with the medullary cells within it, in many cases will be sufficient to dis-

tinguish the hair from every other substance likely to be mistaken for it; but sometimes this cannot be clearly made out, and the marks on the surface may be indistinct; when attention must be directed to its refracting power, well defined smooth outline, and also to the sharply truncated or fibrous ends, or to its dilated club-shaped extremity in the case of the hair bulb. In the latter points, small portions of hair will be found to differ from the cast, for this latter does not refract so strongly; the lines on each side are delicate but well defined, and the ends are seldom broken so abruptly as in the case of the hair. Cat's hair can scarcely be mistaken for any urinary deposit with which I am acquainted, and its transverse markings will serve at once to distinguish it with certainty. (*Illustrations*, Pl. I, figs. 1, 2, 3.)

Cotton and flax fibres are very often found in urine. When broken off in very short pieces, they may be mistaken for casts; but the flattened bands of the former, and the somewhat striated fibres of the latter, will generally be found sufficiently characteristic. (*Illustrations*, Pl. III, fig. 16; Pl. I, fig. 4.)

Portions of feathers are often detected in urinary deposits upon microscopical examination, and are derived, no doubt, from the bed or pillow. The branched character of the fragments will always enable the observer to recognise them with certainty. (*Illustrations*, Pl. III, fig. 14.)

Pieces of silk are not unfrequently present, but these can scarcely be mistaken for any substance derived from the kidney. Their smooth glistening appearance and small diameter at once distinguish them from small portions of urinary casts, and their clear outline and regular size from shreds of mucus, etc.

Fibres of Deal from the Floor. Of all the extraneous matters likely to be met with in urine most calculated to deceive the eye of the observer, none are more puzzling than the short pieces of single fibres of deal. In hospitals, where the floor is uncovered, and frequently swept, portions of the fibres of the wood are detached, and being light, very readily find their

way into any vessel which may be near. In fact, these fibres enter largely into the composition of the dust which is swept up. I was familiar with the appearance of these bodies for a long time before I ascertained their nature; for, although the peculiar character of coniferous wood is sufficiently well marked, when only very small portions are present, and in a situation in which they would scarcely be expected to be met with, their nature may not be so easily made out. Often only two or three pores may be seen, and not unfrequently these are less regular than usual, in which case they may be easily mistaken for a small portion of a cast with two or three cells of epithelium contained within it. I have very frequently met with these fibres amongst the deposit of various specimens of urine which have been obtained from private as well as from hospital patients. (*Illustrations*, Pl. III, fig. 15.)

Starch-granules are very commonly found in urinary deposits, and indeed in all matters subjected to microscopical examination; usually their presence is accidental, but large quantities of starch have often been added for purposes of deception. Their true nature may be discovered, either by their becoming converted into a jelly-like mass on being boiled with a little water in a test-tube, by their behaviour upon the addition of free iodine, or by their well defined microscopical characters. The three kinds of starch most likely to be met with in urine are potatoe starch, wheat starch, or rice starch. They are readily distinguished by microscopical examination. Small portions of potatoe, or pieces of the cellular network in which the starch globules are contained, have been occasionally met with. Under the head of starch may also be included bread-crumbs, which are very commonly present in urine, and have a very peculiar appearance, which may be so easily observed that a description would appear superfluous. Many of the starch-globules will be found cracked in places, but their general characters are not otherwise much altered. (*Illustrations*, Pl. II, figs. 6, 7, 8, 9, 10, 11.)

Portions of tea-leaves are occasionally found in urine. The beautiful structure of the cellular portions, and the presence of minute spiral vessels, distinguish this from every other deposit of extraneous origin. A small piece of a macerated tea-leaf will be found to form a most beautiful microscopic object. (*Illustrations*, Pl. I, fig. 5.)

Milk and certain colouring matters are sometimes purposely added to urine; and it is often difficult to make out whether they have been added with the intention of deceiving us, especially as some colouring matters, such as logwood, Indigo, or Prussian blue (?), when taken into the stomach may be absorbed by the vessels, and eliminated from the system in the urine. A form of Indigo, there can be no doubt, is actually generated in the system. Urine to which milk has been added can be easily distinguished from the so-called chylous or milky urine by its microscopical characters. The presence of small oil-globules, with a well defined dark outline, can always be detected in milk by the aid of the microscope, while in chylous urine nothing but a great number of very minute and scarcely visible granules, composed of fatty matter, can be made out. (*Illustrations*, Pl. III, fig. 13.) The observer should also be familiar with the appearance of oil-globules under the microscope, fig. 12.

Sputum: Epithelium from the Mouth: Vomit. It must be remembered, too, that epithelium from the mouth is often found in urine. All the cells met with in sputum are occasionally found, and a vast number of different substances, which are rejected by vomiting, are from time to time detected. The observer must not be surprised at finding now and then some well defined elementary fibres of striped muscle. It is most difficult to prevent these different substances from being mixed with the urine. They often cause the microscopist great trouble—and especially at first, before the eye has become quite familiar with the appearances, they are likely to give rise to the greatest confusion in descriptions of microscopical appearances. For the microscopical characters of the substances

present in sputum and vomit, I must refer you to the woodcuts in *The Microscope in its application to Practical Medicine*, and the plates in the third part of *Illustrations of the Use of the Microscope in Clinical Medicine*: When we next meet, I propose to commence the description of *urinary deposits*, and shall in the first place allude to the characters of insoluble substances floating upon the surface or diffused through the urine. I shall have to speak of those interesting cases of chylous urine which occasionally come under our notice, and shall advert to the different conditions under which fatty matter occurs in human urine.

LECTURE VIII.

URINE IN DISEASE. 1. SUBSTANCES FLOATING ON THE SURFACE OF THE URINE, OR DIFFUSED THROUGH IT, BUT NOT FORMING A VISIBLE DEPOSIT. *Thin Pellicle formed upon the Surface of Urine. Opalescent Urine. Opalescence produced by Vibriones. Milk in Urine. Chylous Urine. Mr. Cubitt's Case. Analyses of the Urine. Microscopical Characters of the Deposit. Dr. Bence Jones's Case. Dr. Priestley's Case. Of the Treatment of Cases of Chylous Urine.* FATTY MATTER IN URINE. *Different States in which Fatty Matter occurs in Urine. Cholesterine in Urine. Composition of Fatty Matter passed in Cases of Fatty Degeneration of the Kidney. Kiestein.* OTHER FORMS IN WHICH FATTY MATTER OCCURS IN URINE. *Urostealith. Fluid Yellow Fat. Fatty Matter in Rabbits' Urine. Erroneous Observations connected with the Presence of Fatty Matter in Urine.*

Thin Pellicle formed upon the Surface of Urine. Several different substances are found from time to time floating on the surface of urine; but, for the most part, these are merely buoyed up by a thin pellicle, which is probably formed by the action of the air on the urine leading to the decomposition of some of its constituents, which causes the precipitation of the phosphates mixed with organic matter in the form of a thin pellicle. Triple phosphate is also deposited in the pellicle, in a crystalline form, some of the crystals being exceedingly minute, but still exhibiting their well known characters. A similar pellicle may always be formed, if urine be somewhat concentrated by evaporation; but in this case a large quantity

of urate of soda is entangled in the pellicle. It crystallises in the form of small spherical masses, from all sides of which little spicules project.

Fatty matter is often found floating upon the surface of urine, especially when it has fallen in accidentally. One form of fatty matter has been described under the name of kiestein, which was said to be constantly present in the urine of pregnant women.

Urates occasionally accumulate upon the surface of urine, but present nothing peculiar for remark.

Opalescent Urine. The turbidity or opalescence of urine is most frequently due to the presence of urates in an exceedingly minute state of division. The precipitate may be so fine and so light that it will not sink to the bottom and leave a clear supernatant fluid. The urine is perfectly clear when passed, but becomes turbid afterwards. Upon the application of a gentle heat, the turbidity is instantly removed. In urine of high specific gravity, many substances are held in suspension which would form a deposit in fluids of ordinary density. It is not uncommon to meet with pus or blood thus diffused through the urine. If mucus be present too in large proportion, many substances which usually form deposits will be buoyed up as it were, and evenly diffused through the fluid, although generally these substances subside more or less.

Opalescence produced by Vibriones. Some specimens of urine become decomposed very soon after they have been passed; others are voided in a state of incipient decomposition. Such specimens are found turbid, and look as if they had been mixed with a very small quantity of milk. Upon microscopical examination, it will be found that this turbidity depends entirely upon multitudes of some of the lowest organisms, consisting of different forms of fungi and other little elongated bodies termed vibriones, which are considered by some authorities to be animals, while others class them with

vegetables. My own observations have led me to entertain the latter opinion with regard to their nature.

Milk is often added to urine, for the purpose of deceiving us, and is of course diffused through the fluid, the degree of opalescence varying according to the quantity of milk added. Milk can always be detected upon microscopical examination by the presence of the numerous oil-globules, and by the circumstance of the milky fluid becoming quite clear after agitation with a little ether and a few drops of acetic acid or carbonate of potash, which will dissolve the envelopes of casein around the globules, and thus the oily matter becomes exposed to the solvent action of the ether. By the addition of a little acetic acid, the casein of the milk is precipitated.

Chylous Urine.

The most important substance which gives to urine an opalescent appearance, and at the same time causes it to resemble milk, is fatty matter in a very minute state of division —in a *molecular state*, as it is termed. Such urine, under the microscope, is seen to contain a considerable quantity of the most minute particles, which exhibit molecular movements. These particles are not altered by a moderate heat, but are dissolved in great measure, though often not entirely, if the urine be agitated with ether. Urine possessing these characters is termed chylous urine. The cases in which it occurs are very interesting, and I propose to call your attention to some points connected with this condition. Cases of chylous urine are very seldom met with in this country, but I have been told by many friends that they are comparatively common in warm climates.

The following interesting case occurred in the practice of my friend Mr. Cubitt of Stroud, to whom I am indebted for the notes, and also for the specimens of urine which I analysed.

Mr. Cubitt's Case. "Mrs. S., aged 50, native of Norfolk, in which county she has always resided, has been married twenty-

nine years, and has had five children, the last of whom died in its second year. The youngest now living is 20. The catamenia ceased at 43.

"Till within the last four years, she has usually enjoyed good health, but at that time had a severe attack of influenza. She continued more or less out of health during the six or nine following months, and soon after this period her urine assumed a milky appearance, which character it has retained up to the present time (November 1849), except at intervals of unfrequent occurrence and of short duration. The disorder would seem to have been gradually progressive, as the urine, which was at first only turbid and opalescent, has become by degrees more and more opaque, so that when I saw it, the unassisted eye could not distinguish between it and milk; moreover, after the lapse of a few days, a rich kind of cream rises to the surface. It is almost entirely free from any urinous odour, and has a faint, sweetish smell, something resembling that of ripe apples. In the mean time, the general health has been more and more failing, and the digestive functions imperfectly performed; the patient has complained of loss of appetite, pain at the epigastrium after eating, slight headache with nausea, palpitations, and other dyspeptic symptoms. She has been losing flesh, suffers from pain in the back and loins without tenderness, from aching of the limbs, incapability of exertion, and other evidences of general debility; but still when the duration of the disease is taken into account, the general health may, upon the whole, be said to have suffered little. She states that throughout the affection, fatigue, whether of mind or body, unusual exertion, excitement, late hours, distress, anxiety, immediately render the milky character of the urine more marked. She has been under the care of several medical men, as well as of some professed quacks (none of whom have ever examined the urine), without benefit; nevertheless, she has found that for the time, brandy and isinglass, or compound spirits of lavender, have never failed

to clear the urine, but without at all improving the general health. She seems to derive *temporary relief from all kind of stimulants.* Occasionally, and without any apparent cause, the urine reassumes its ordinary appearance, but this is of rare occurrence, and its duration never exceeds two or three days. At no one time has she passed milky urine *during the day.* It is only the urine passed in the morning, after the night's sleep, which has ever presented a milky character. Occasionally, this urine settles down into a tremulous jelly, which takes the shape of the containing vessel, and more than once this spontaneous coagulation has taken place within the bladder itself; and in consequence of the impaction of small masses in the urethra, the patient has suffered from temporary retention of urine. She has tried various kinds of diet, but without any visible effect upon the urine. The quantity secreted appears normal, and there is no unusual frequency of micturition. The appetite has never been inordinate, or the thirst unnatural; the bowels are inclined to be costive. There is nothing remarkable about the state of the skin. She has suffered a good deal from pain in the back and loins, but there is no tenderness in this locality, and the uneasiness seems to depend upon exertion, and appears to be connected with general debility. There has never been any dropsy, and she has suffered from no cardiac or pulmonary symptoms, but such as may be accounted for by the dyspepsia; but I have not had an opportunity of examining the chest. She has never had severe headache, vertigo, vomiting, or other cerebral symptoms. Has never had rheumatism, fever, or any inflammatory attack, has not been salivated, and has no reason to suppose she has suffered from exposure to cold. At the time when I saw her, the tongue was slightly furred, pulse 70, small and soft, respiration 20, and the skin cool; but there was a haggard appearance about the countenance, and a dark circle around the eyes, with slight bagging of the skin in this situation."

Mr. Cubitt inquired as to this patient's state in April 1857,

and informed me that occasionally she passes chylous urine, but only for a short time. The symptoms seem to have become less marked. She has been taking no medicine, and latterly has been in better general health than for several years past.

Analyses of the Urine. The first specimen of urine was passed in the morning. It was perfectly fluid, and had all the appearance of fresh milk. It had neither a urinous smell nor taste. Upon the addition of an equal volume of ether it became perfectly clear; but when the ether was allowed to evaporate by the application of a gentle heat, the fatty matter could be again diffused, by agitation, through the urine, which regained its milky appearance, although it appeared rather more transparent than before the addition of the ether. Upon examination, however, by the microscope, instead of the minute granules visible in the first instance, numerous large and well defined oil-globules were observed.

Specific gravity, 1013. *Reaction*, neutral.

A little of the urine was evaporated to dryness. The dry residue was very greasy to the touch. It was treated with ether, and upon evaporating the ethereal solution, a considerable quantity of hard and colourless fat was obtained.

Analysis 55.

The urine was found to contain in 1000 parts—

Water	947·4	
Solid matter	52·6	
Urea	7·73	
Albumen	13·00	
Extractive matter with uric acid	11·66	
Fat insoluble in hot and cold alcohol, but soluble in ether	9·20	13·9
Fat insoluble in cold alcohol	2·70	
Fat soluble in cold alcohol	2·00	
Alkaline sulphates and chlorides	1·65	
Phosphates	4·66	

The second specimen was passed during the same day. It

was slightly turbid, but contained a mere trace of deposit, consisting of a little epithelium, with a few cells larger than lymph corpuscles, and a few small cells, probably minute fungi. Not the slightest precipitate was produced by the application of heat, or by the addition of nitric acid.

Specific gravity, 1010. *Reaction*, very slightly acid.

Analysis 56.

In 1000 parts it contained—

Water	978·8	
Solid matter	21·2	
Urea	6·95	
Uric acid	·15	
Extractive matter	7·31	
Fatty matter	0	
Alkaline sulphates and chlorides	5·34	
Alkaline phosphates	1·45	1·60
Earthy phosphates	·15	

The presence of so large a proportion of fatty matter, perhaps combined with the albumen (13·9 grains), in the first specimen, and its complete absence in the second, which was passed only a few hours afterwards, is very interesting, and bears upon the pathology of this strange condition.

The proportion of the constituents in 100 grains of the solid matter of these two specimens of urine, is given in the following table. 55, is the chylous; 56, the clear specimen:—

	55.	56.
Solid matter	100·00	100·00
Urea	14·69	32·78
Albumen	24·71	—
Extractive matter, uric acid	22·17	35·18
Fatty matter	26·43	—
Alkaline sulphates and chlorides	3·14	25·18
Phosphates	8·86	7·54

Microscopical Characters of the Deposit. The slight deposit which formed after the chylous urine had been allowed to stand for some time in a conical glass vessel, consisted of a

small quantity of vesical epithelium, and some small slightly granular circular cells about the size of a blood-corpuscle.

No oil-globules could be detected upon the surface of the urine or amongst the deposit, and the fatty matter, which was equally diffused throughout, was in a molecular or granular

Fig. 23.—Deposit from chylous urine, showing fatty matter in a molecular state. 215 diameters.

form. By examining the urine with the highest powers, only very minute granules could be detected. These exhibited molecular movements. Indeed, it may be said, that the microscopical characters of this urine closely resembled those of chyle.

Only a few of the granular cells could be discovered in the clear specimen, in which there was scarcely any visible deposit.

In a case which occurred in the practice of Mr. Gossett, and which is related by Dr. Golding Bird, an alternation in the character of the urine similar to that noticed in the present case occurred. The urine which was passed in the morning was chylous, while that secreted some hours afterwards was clear, pale, and transparent. The clear specimens, however, contained albumen. The chylous specimen which I examined did not coagulate spontaneously, as often occurs in these cases. In the case reported by Dr. Bence Jones, specimens of urine were frequently passed which were perfectly clear.

L'Hèretier, and the late Dr. Franz Simon, of Berlin, state that these specimens of milky looking urine contain oil-globules; but the greater number of authors who have met with such cases have failed to detect oil-globules in the urine. In the present instance they were certainly absent, and the fatty matter existed in a molecular form only.

In Dr. Bence Jones's case, oil-globules were found in one or two instances; but in other specimens the fatty matter was present in a molecular state.

In true cases of chylous urine, the fatty matter, in a molecular state, seems to filter through the walls of the vessels, and escapes at once into the urine, while in cases of fatty degeneration of the kidney, in which actual globules are observed, the fatty matter exists in the interior of the cells, where it remains a sufficient time to become converted into distinct oil-globules. Globules thus formed may afterwards become separated from each other, and may appear in the urine as free oil-globules. It is, however, very probable, that after chylous urine has been allowed to stand for some time, the granular fatty matter may become aggregated in masses, so as to form distinct oil-globules.

Dr. Bence Jones's Case. In a case of albuminous and fatty urine, reported by Dr. Bence Jones (*Medico-Chirurgical Transactions*, vol. xxxiii), oil-globules and streaks of oil were detected upon the surface of the urine which was passed in the morning, by microscopical examination. In two other specimens passed later in the day, fatty matter in a molecular form, but no oil-globules, was discovered. Upon standing, a coagulum formed in the urine. These specimens contained about 50 grains of solid matter in 1000 of urine. The patient was a Scotchman, aged 32. His work was hard, and he was subject to privations. The urine was first observed to be thick and white about Christmas 1848; and at this time, the chief symptom from which he suffered, was acute pain in the loins.

Lehmann is, as far as I know, the only observer who states

that chylous urine never owes its opacity to fat (vol. iii, p. 544). I have now seen several cases, and in all the opacity was due to fatty matter. Authorities generally are quite agreed upon this point; but some state that the fat is sometimes in the form of globules. It is probably combined with albumen.

Many of the patients whose cases are recorded, have suffered from severe pain in the region of the kidneys; but this may be accounted for by general debility, associated with this condition of urine, as well as on the supposition of the existence of organic disease of the kidneys. Indeed, the pain referred to in this locality, seems to partake more of the character of muscular pain than of pain seated in the kidneys themselves.

The following are two analyses of the urine in Dr. Bence Jones's case. The first was made on October 19th, and the second was passed some time afterwards, on the same day on which the patient was bled.

Analyses	57	58
Water	955·58	943·13
Solid matter . . .	44·42	56·87
Albumen . . .	14·03	13·95
Urea	13·26	24·06
Fatty matter . .	8·37	7·46
Saline residue . .	8·01	10·80
Loss	·75	·60

The chylous urine contained blood-corpuscles. The serum of the blood was not milky, but the blood contained in 1000 parts 240·03 of solid residue, which contained of fatty matter ·62; fibrine, 2·63; blood globules, 159·3; solids of serum, 78·1.

Dr. Bence Jones showed, in some valuable experiments on this case, that during complete rest albumen was not passed. (*Phil. Trans.*, 1850.)

The urine was not chylous from February 14th, 1850, to October 4th, 1851, when it was again slightly chylous. The

beneficial change was entirely attributable to gallic acid. At first, twenty grains three times a day were given, but this was afterwards diminished.

Dr. Bence Jones mentions another case of a gentleman, aged 40, who passed the greater part of his life in the West Indies. The chylous condition of the urine was increased both by mental and bodily exertion. The urine was sometimes clear for several days together, sometimes white after dinner, and clear all the rest of the day. It was more frequently chylous after animal than after vegetable food.

Dr. Priestley's Case. This occurred in a boy who was only 11 years of age. (*Medical Times and Gazette*, April 18th, 1857.) He was born at the Cape of Good Hope, and was taken as a child to the Isle of France, and while there had frequent attacks of hæmaturia and chylous urine. The attacks came on at intervals of weeks or months. He was placed in the autumn of 1855 under the care of Dr. Simpson of Edinburgh. Various plans of treatment were tried in vain. He was confined to the house, and passed as much as fifty to fifty-five ounces of chylous urine daily. He gradually became weaker, and died apparently from asthenia. A fortnight before death, the urine lost its milky appearance, and the feet became œdematous. Every tissue appeared bloodless, and there was considerable emaciation. The kidneys were pale, rather larger than natural. Throughout the greater part of both kidneys the epithelium was found to contain numerous oil-globules. Dr. Priestley suggests the possibility that this case of chylous urine may have been associated with Bright's disease.

No lesion likely to account for the production of the chylous urine has been met with in the *post mortem* examinations of the cases of this condition which have been made; and most observers consider that the chylous condition of the urine does not depend upon a morbid state of the kidneys. Dr. Elliotson, on the other hand, inclines to the view that the kidneys are to be regarded as the seat of the affection. He gives the history

of a very interesting case in the *Medical Times and Gazette* for September 19th, 1857.

Of the Treatment of cases of Chylous Urine. Various plans of treatment have been tried in cases of chylous urine, but without very satisfactory results. Astringents have proved useful in many instances; and in one of Dr. Bence Jones's cases, the pressure of a tight belt "relieved the pain, and rendered the urine slightly less chylous."

Dr. Prout found that in some of his cases temporary relief resulted from the use of the mineral acids and astringents, as alum and acetate of lead. Opium also arrested some of the symptoms for a while. Dr. Bence Jones has tried a variety of remedies, but the greatest advantage seems to have been derived from the use of astringents. Tannic acid, acetate of lead, and nitrate of silver, were employed. Matico afforded some relief, but the most valuable remedy in Dr. Bence Jones's hands was gallic acid. Its good effects were probably due to its astringent properties, and not to any specific action. The chylous character of the urine and the albumen disappeared two days after the commencement of the use of this drug; and one case seems to have been cured by its long continued use. (For the results of a daily examination of the urine for some weeks while the patient was on gallic acid, see *Phil. Trans.*, 1850.)

In Dr. Priestley's case, the gallic acid caused such nausea that it was considered expedient to abandon its use.

Gallic acid was also tried by Dr. Goodwin of Norwich, in a case which came under his care. He says: "Gallic acid appeared to exert great influence in restraining the milky appearance of the urine. The patient took it for about nine months in 1855 and 1856; and I found his water perfectly normal in colour after six months steady use of it in doses of half a drachm three times a day. He then discontinued its use, and went to work. In four or five days, the same milky appearance presented itself, and was again removed by taking the gallic

acid. He could at any time render the urine nearly normal in appearance by taking this drug; but it was necessary to avoid hard work. He only complained of occasional dimness of sight and deafness; but it was not easy to make out to what cause these symptoms were due. He left off attending the hospital in September last, when my note is as follows:—Has not had any gallic acid for three weeks, and the urine is now slightly opaline in appearance. Specific gravity, 1010; the temperature of air was about 50°. He passes seven pints and a half daily on the average. It does not coagulate with heat or nitric acid, or both combined."

Dr. Goodwin has not been able to ascertain anything of the further history of the case since September.

The very large quantity of fatty matter present in the first specimen of urine, and its total absence in the urine passed only a few hours afterwards, is remarkable in Mr. Cubitt's case, and confirms the conclusions which previous observers have arrived at with reference to this condition; viz., that the fatty matter appears in largest quantity after the absorption of chyle; although in Dr. Bence Jones's case it did not appear to be associated with any fatty condition of the blood. In Mr. Cubitt's case, we may, I think, conclude that there is no organic disease of the kidneys. First, from the absence of any symptoms; secondly, from the microscopical characters of the deposit; and, thirdly, from the fact that albumen was only present when the urine contained the fatty matter.

Upon reviewing the chief points in this and other cases, one is led to conclude that the condition does not depend upon any permanent *morbid* change in the secreting structure of the kidney, and that the chylous character of the urine is intimately connected with the absorption of chyle. The debility and emaciation shew that the fatty matter, albumen, and other nutritive substances, are diverted from their proper course, and removed in the urine, instead of being appropriated to the nutrition of the system. Whether these materials are separated

from the blood by the kidneys, or find their way to these organs by some more direct course, cannot now be decided.

I trust that practitioners who have opportunities of examining many of these cases in the West Indies, will afford us assistance in endeavouring to ascertain the nature of this curious condition. Careful reports of the most marked cases are much to be desired. In *post mortem* examinations, the serum of the blood should be collected and allowed to stand, in order to see if it were milky or not. The state of the mesenteric glands, lacteals, and receptaculum chyli, should be particularly examined, and it would be desirable to inject the thoracic duct, first with transparent fluid injection, and afterwards distend it with a little strong size, when the course of the absorbent trunks might be traced, and, if necessary, parts subjected to microscopical examination.

Fatty Matter in Urine.

Different States in which Fatty Matter occurs in Urine. Let us now consider in what different conditions fatty matter has been found in urine. These may be briefly stated as follows:—

1. *In a molecular state*, as in chylous urine.
2. *In the form of globules*, as when oil, fatty matter, or milk, have been added to urine.
3. *In the form of globules*, free in the deposit, enclosed in cells (fat-cell), or entangled in casts.
4. *Dissolved* in small quantity by other constituents, so that its presence can only be detected by chemical examination.
5. *In the form of concretions* (urostealith, as described in one solitary case by Heller).
6. *In a fluid state*, of which two cases are reported by Dr. C. Mettenheimer.

We have already discussed the subject of chylous urine, and have referred to the admixture of oil, butter, and milk, with this secretion. The whole question of fatty matter, as it

occurs inclosed in cells, is a very interesting one, and well worthy of our attention. I have examined several specimens of fatty matter, obtained from various structures in a state of fatty degeneration; and the characters of the fat, at least in some important particulars, are the same in all.

Cholesterine in Urine: Composition of Fatty Matter passed in Cases of Fatty Degeneration of the Kidney. Some years ago (1850), when examining the fatty matter which accumulates in the epithelial cells passed in the urine in great number in cases of fatty degeneration of the kidney, I was surprised to find that it contained a considerable quantity of cholesterine. The only cases in which cholesterine seems to have been detected in urine, are those which are referred to in Simon's *Chemistry*. Gmelin is said to have found cholesterine in the urine in a case in which the flow of bile was impeded; and Möller twice detected it in kiestein, the film which rises to the surface of the urine of pregnant women, and contains sometimes much fatty matter. (Casper's *Wochenschr.*, Jan. 11—18, 1845; quoted in Franz Simon's *Animal Chemistry*, vol. ii, pp. 313, 333.) It is not stated, however, in these cases, if the crystalline form of the crystals was made out.

Other authorities, among whom is Lehmann, state that cholesterine has not been detected in urine.

The first case which I examined was that of John Ryan, a patient in King's College Hospital in 1850, under the care of Dr. Todd. The urine was pale, of acid reaction; specific gravity 1020, and contained albumen. The pale flocculent deposit consisted principally of fat cells.

The deposit from upwards of seven gallons of urine was collected upon a filter. It was dried over a water-bath, and digested in a mixture of alcohol and ether. The solution was filtered, and after being concentrated by evaporation, was allowed to cool. Crystals of cholesterine were formed in considerable number. These were subjected to microscopical examination. The fatty matter in this case was found to be

composed of at least three distinct forms of fat; but in consequence of the very small quantity obtained for observation, it was not possible to examine their characters very minutely. The deposit from this urine contained—

1. A dark brown fat in very small quantity, which was soluble in ether, but insoluble in hot and cold alcohol.

2. A light brown saponifiable fat, soluble in hot but insoluble in cold alcohol.

3. A considerable quantity of pure *cholesterine*, which originally existed in the urine dissolved in the other fats.

The next case of fatty degeneration of the kidney submitted to examination was that of a man named Tiedeman, also a patient of Dr. Todd's, in King's College Hospital. The case is published in Dr. Todd's *Clinical Lectures* (Case 107). See also *Archives of Medicine*, vol. i, page 8. The fatty matter obtained from twenty-four pints of urine weighed only ·47 grains, but from this a great number of crystals of cholesterine were obtained by extraction with alcohol.

The deposit of the urine of a third case of fatty degeneration of the kidney has been submitted to examination, and cholesterine has been discovered in this instance also.

In one case in which the deposit had been kept for some time in a preservative fluid consisting of wood-naphtha, creasote, and water, the cholesterine had separated from the other constituents of the oil-globules, in the form of rhomboidal tablets.

The fatty matter deposited in the kidney in these cases also contains a large proportion of cholesterine; and I have detected the presence of cholesterine in the fatty matter of so many organs in a state of fatty degeneration, as to justify the conclusion that the formation of this substance is intimately connected with the changes taking place in this morbid process.

When cholesterine occurs in the urine, it is always dissolved in other fatty matters, so that its presence cannot be detected except by extraction with alcohol and subsequent crystallisa-

tion. It forms a part of the constituents of the minute fat-globules contained in the epithelial cells and casts of the uriniferous tubes, which Dr. Johnson has proved to be so characteristic of this form of kidney-disease.

Surprise has often been excited by observing that oil-globules passed in the urine in these cases, sink to the bottom of the vessel, when we should expect rather to find the fatty matter rising to the surface by reason of its lightness. That the cell-walls and casts are not the sole cause of this subsidence, is proved by the fact that individual oil-globules, quite free from these structures, are frequently found at the bottom of the vessel with the deposit. This subsidence is probably in some measure due to the quantity of the cholesterine entering into the composition of the fatty matter. Crystals of cholesterine sink in fluids of a specific gravity even some degrees above 1000.

I have not been able to detect cholesterine in the urine in any other morbid condition than in that above referred to. Although I have at present only searched for it in four cases of fatty degeneration, in consequence of the difficulty of obtaining sufficient quantity of the deposit to work upon, the circumstances which I have enumerated render it very probable that it is a constituent of the fatty matter present in the urine in all cases of fatty degeneration of the kidney.

I shall have occasion to describe elsewhere the characters of the fatty matter present in other tissues in a state of fatty degeneration; but I may remark here that cholesterine is a very constant constituent, and I have detected it in the large cells (*granular corpuscles*) containing oil-globules, which are abundant in the fluid of *ovarian dropsy, and sometimes in hydrocele*, and in that found in cysts generally;* in similar cells, which

* The bodies described as *granular corpuscles, inflammation globules, compound granular cells, exudation corpuscles*, and known by other names, are really composed of a number of minute oil-globules, aggregated together in the form of a spherical mass which not unfrequently becomes invested with albuminous matter, resembling a cell-wall; but I believe that usually the albuminous material is deposited with the oil-globules, and therefore that no true envelope or *cell-wall* exists.

are common in *sputum*, and are derived from the surface of the mucous membrane of the bronchial tubes; in the cells which are frequently very numerous about the *small arteries of the brain* in cases of *white softening*, in those found in cases of the so-called *fatty degeneration of the placenta*, and in other situations.

Kiestein. Of this peculiar substance I can give you no very satisfactory account. Some years since, numerous observations were made by Nauche, and repeated by Dr. Golding Bird and several other observers, with the view of ascertaining if there was any foundation for the statement that, in pregnant women, certain elements of the milk found their way into the urine, and, after the lapse of a short time (twenty-four hours to five or six days), a thin pellicle consisting of fatty matter, a substance allied to casein, and crystals of triple phosphate, formed upon the surface. Some went so far as to say that the presence of this pellicle was sufficient to indicate the existence of the pregnant state. This statement has, however, long since been proved to have no foundation in actual observation. In some of the cases brought forward by Dr. Golding Bird, the pellicle was absent; in others, the pellicle was observed; and the conclusion he arrived at was, that in cases in which the pellicle was formed, it was due to the presence of certain constituents of the milk, which, from not escaping from the gland in the usual way, had been reabsorbed and separated from the blood by the kidneys. I have not unfrequently seen a pellicle composed of animal matter, in which vibriones and fungi were abundant, and crystals of triple phosphate formed upon the surface of various specimens of urine which had been left to stand for a day or two, both from the male and from the female. Whether this is exactly the same sort of pellicle as that said to form upon the urine of pregnant women, I cannot say; but it possessed the characters usually assigned to the so-called kiestein. The animal matter has not been satisfactorily isolated, and is in many cases undergoing decomposition. In the

absence of more exact information, I think we can attach no importance to the presence of this pellicle in the diagnosis of pregnancy. It may be absent in the pregnant state; and it may be present in the male, and in the unimpregnated, as well as in the impregnated female.

Other Forms in which Fatty Matter occurs in Urine.

Urostealith. Dr. F. Heller reports a very remarkable case, in which small concretions, composed of fatty matter, were passed in the urine. The patient was a man, twenty-four years old, who suffered from symptoms of stone in the bladder. He passed several small solid bodies, which were found by Dr. Heller to consist of a peculiar form of fatty substance, to which he gave the name of urostealith. The man, who was treated with carbonate of potash, got quite well in a fortnight (quoted in Dr. Golding Bird's work, edited by Dr. Birkett, p. 422; Heller's *Archiv*, 1844, s. 97, 1845, s. 1). Dr. Moore of Dublin has confirmed Heller's observations on urostealith. He examined specimens of this curious substance, which he received from Dr. Robert Adams of Dublin, and Dr. Little of Sligo (*Dublin Quarterly Journal of Medical Science*, May 1854, vol. xvii, p. 473).

Fluid Yellow Fat. Dr. C. Mettenheimer gives two cases in which large quantities of fluid yellow fat were passed in the urine. The first was a man suffering from cancer of the lungs, who was taking a tablespoonful of cod-liver oil twice a day. The second was that of a woman who was recovering from acute inflammation of the kidneys, and was taking a mixture composed of henbane and hemp. (*Archiv des Vereins*, B. 1, Heft 3.)

Fatty Matter in Rabbits' Urine. Dr. Siegmund found a quantity of fatty matter in the urine of rabbits to which cubebs had been given. The excretion of fatty matter continued as long as the cubebs were administered. After death, no morbid change was discovered. It disappeared when the cubebs were

omitted, but reappeared when they were administered again. The same observer also found that, although cantharides and cubebs irritated the kidney, they did not diminish the proportion of urea excreted.

Erroneous Observations connected with the Presence of Fatty Matter in Urine. Numerous other instances, in which fat has been said to have been passed in considerable quantity, are on record; but there can be little doubt that, in many of these cases, the chemical characters of the substance supposed to be fatty were not carefully ascertained. There is reason to believe that the iridescent pellicle, which really consists principally of fungi, vibriones, and crystals of triple phosphate, from its general resemblance to a thin film of oily matter, was mistaken for fat. Many practitioners have been deceived in consequence of the admixture of milk with urine. This is not an uncommon practice, and we should be very careful not to be misled by impositions of this kind. It is hardly credible what trouble some patients will take to deceive us; and very often deception is practised and carried on for a long time without detection. From not being able to discover any reasonable motive, we are sometimes too ready to conclude that our suspicions are unfounded; and thus we may be led to believe statements which are really false, and report cases apparently of a very exceptional character, which only prove that great ingenuity has been employed for the mere purpose of imposing upon us.*

In Lecture IX, we shall examine those sediments which I include under the head of light and flocculent urinary deposits. This class includes the different forms of epithelium from the urinary passages, spermatozoa, casts of the uriniferous tubes, and many other bodies which are of great clinical importance.

* I am much interested in the question of the removal of fatty matter by the kidneys; and I shall be very much obliged to any one who will send me specimens of urine containing fatty matters in any unusual form, or reports of well authenticated cases.

LECTURE IX.

Urine in Disease. 2. Of Light and Flocculent Deposits. *Mucus. Vibriones. Torulæ, including the Sugar-Fungus and Penicillum Glaucum. Sarcinæ. Trichomonas Vaginæ. Epithelium of the Genito-urinary Passages, Ureter, Bladder, Urethra, Vagina. Spermatozoa. Vegetable Bodies resembling Spermatozoa. Benzoic Acid. Casts of the Renal Tubes.* A. *Casts of Medium Diameter, about the one-seven-hundredth of an inch. Epithelial Casts. Casts containing Dumb Bells. Granular Epithelial Casts. Casts containing Oil. Fat-Cells. Casts containing Blood. Casts containing Pus.* B. *Casts of considerable Diameter, about the one-five-hundredth of an inch. Large Waxy Casts.* C. *Casts of Small Diameter, about the one-thousandth of an inch. Small Waxy Casts. Of Casts in a clinical point of view.*

Gentlemen,—We have already considered the characters of the three classes of urinary deposits, and we will now proceed to examine the different substances comprised in the first class, which includes light and flocculent deposits. Many of them occupy a considerable bulk, although the actual quantity of matter entering into the formation of the deposit is exceedingly small. If dried, one of the most bulky of these deposits from six or eight ounces of urine would hardly weigh half a grain.

II.—First Class of Urinary Deposits.

Mucus. If healthy urine be allowed to stand for a few hours after it has been passed, a bulky, flocculent, and very transparent cloud will be deposited towards the lower part. Upon examining this in the microscope, we see a few delicately

granular cells, rather larger than a blood-corpuscle, scattered sparingly through a clear and perfectly transparent substance, in which only a few minute granular points can be detected. A few cells of epithelium from the bladder, or from some other part of the urinary mucous membrane, are not unfrequently met with. Nothing more is observed in the mucus found in healthy urine. In disease, however, this mucus increases in quantity, and forms a thick transparent deposit, containing numerous cells similar to those above referred to, with much epithelium, the character of which depends upon the particular part of the mucous membrane affected. The characters of mucus are represented in Fig. 24. Little collections of mucus, with imperfectly formed cells, are not unfrequently met with in urine. These are generally derived from the follicle of the urethra, or from the prostate. Long shreds of mucus-like material are sometimes formed in the seminal tubules, and escape with the urine. (*Illustrations*, Pl. xiii, Fig. 2.)

Fig. 24.—Mucus and small granular cells from healthy urine. The large cell is from the bladder. × 215.

The very thick glairy deposit, which is frequently found in the urine in cases of disease of the bladder, must not be mistaken for mucus. This consists of pus altered by the action of carbonate of ammonia which has been set free in consequence of the decomposition of the urea by the action of some animal matter acting upon it as a ferment, after it has left the bladder. In some cases, this change even commences in the bladder itself; and the expulsion of the viscid substance often gives rise to serious inconvenience. When we attempt to draw off the urine with a catheter, the instrument becomes completely plugged up. Urine of this kind exhibits a highly alkaline

reaction, evolves an ammoniacal odour, and frequently contains a considerable deposit of crystals of the triple or ammoniaco-magnesian phosphate, with granules of phosphate of lime. I have observed in several cases, that when the pus came from an abscess in the kidney, or from the pelvis of the kidney, it was not accompanied with crystals of triple phosphate. When it is derived from the bladder, earthy salts are generally present. This point should be taken into consideration before arriving at a diagnosis in doubtful cases. Liquor ammoniæ and potash exert an action upon pus similar to that of carbonate of ammonia.

It should, however, be borne in mind that, if basic phosphate of soda be added to urine, ammonia is always set free in considerable quantity. Dr. G. O. Rees suggests that the ammonia is often set free in this manner, and not by the decomposition of the urea. The same observer (Lettsomian Lectures, *Med. Gaz.*, 1851) considers that the alkalinity of the urine is dependent in certain cases upon the secretion of a large quantity of an alkaline fluid from the mucous membrane of the bladder. When the mucous membrane is exposed, it is always found to be moistened by an alkaline fluid. When irritated, a quantity more than sufficient to neutralise the acidity of the urine is poured out. Dr. Rees explains the fact, that the acid reaction of urine not unfrequently becomes more intense after giving alkalies, by supposing that the alkali allays the irritable state of the mucous membrane, which in consequence secretes less of the alkaline fluid. In injuries to the spine, the beneficial action of alkalies is explained by supposing that the mucous membrane requires a greater quantity of alkali to protect it than in health. Still it is difficult to associate this explanation with the fact that healthy urine is *always* acid. If a slight excess of this *natural* acid really endangered the integrity of the mucous membrane, by exciting the secretion of excess of a *destructive* alkaline substance, one is almost forced to the false conclusion that the actual condition which exists is not so

advantageous to the individual as the existence of a mucous membrane adapted to bear without change the constant action of an acid fluid would be.

Dr. G. O. Rees, as is well known, has also shown that in many cases the urine is actually secreted alkaline; indeed, he was the first observer who showed "that the degree of the acidity of the urine may to a certain extent be regarded as a measure of the acidity of the stomach".

The mucus which is deposited from many specimens of urine often contains a great number of octohedral crystals of oxalate of lime, frequently so very minute as to appear, under a power of two hundred diameters, like a number of dark square shaped spots. Their crystalline form may be demonstrated by the use of a very high power; but they may be recognised with certainty with a little practice, as their square shape presents a characteristic appearance, with which the eye soon becomes familiar. They are insoluble in a solution of potash, and also in strong acetic acid. These crystals are commonly not deposited until after the urine has left the bladder; and if it be allowed to stand for a longer period, they frequently undergo a great increase in size. Fragments of hair, small portions of cotton fibre, and other substances of accidental presence, are not unfreqently encrusted with them.

Vibriones. After urine containing a little epithelium or other animal matter has been allowed to stand for some time, numerous elongated bodies, varying much in length and possessing active movements, are developed in it. These little bodies appear as simple lines under a magnifying power of two hundred diameters; but, by careful focussing, under one of five hundred or six hundred diameters, the longest of them are seen to consist of filaments with numerous transverse lines, indicating a similarity of structure with some of the lower vegetables. They sometimes very closely resemble one of the algæ ordinarily found in the mouth. Most observers agree as to the vegetable nature of the bodies in question; but

Dr. Hassall has recently arrived at the conclusion that they are animal, and that the movements are voluntary (*Lancet*, Nov. 19th, 1859). That the movements are not merely molecular, is quite certain; but it seems to me that much stronger evidence of the animal nature of the vibriones is required than is afforded by the character of their movements, before we are justified in regarding them as animals. As investigation proceeds, the conclusion that many forms, which were considered animal, are really of a vegetable nature, is more frequently forced upon us than that organisms hitherto held to be vegetable, must really be regarded as animal. There is little to be gained by attempts to draw an arbitrary line between the lowest classes of the animal and vegetable kingdom.

These vegetable organisms are seen as minute lines under the microscope; and they undergo very active movements, the longer ones twisting about in a serpentine manner. They are sometimes developed in urine before it has left the bladder, and always occur in decomposing urine.

Other organisms are frequently met with in urine. Numerous forms of animalcules, one of which Dr. Hassall includes in the genus *bodo* (*bodo urinarius*), are also observed in various specimens of urine. It is probable that many of these forms merely indicate different stages of existence of one species.

Torulæ, including the Sugar Fungus and Penicillum Glaucum. Certain forms of vegetable fungi or torulæ are developed in urine after it has been standing for some time. The period which elapses before the appearance of the fungi, and the particular species which is developed, vary much in different specimens of urine, and in different cases of disease. In diabetes, torulæ are often developed in quantity very soon (within a few hours) after the urine has been passed; and their growth at this early period leads the observer to suspect the presence of sugar, which must be confirmed by the application of chemical tests. (Lecture v.) Different forms of fungi are repre-

sented in the *Illustrations*, Pl. xix, Figs. 1 to 7; Pl. xxi, Fig. 6; Pl. xxiii, Figs. 2, 3, 4, 5.

Dr. Hassall has communicated a most interesting paper upon the development of torulæ in the urine, to the Royal Medical and Chirurgical Society, which will be found in the volume of *Transactions* for 1853. Dr. Hassall arrives at the conclusion that there is a species of fungus which is developed in specimens of urine, containing even very minute traces of sugar, which may be looked upon as characteristic of the presence of this substance, as it occurs in no other condition of the urine. This is the sugar fungus; but most observers are agreed that the characters of the fungus are by no means sufficiently constant to enable us to conclude as to the presence or absence of sugar in the urine. The sugar fungus in diabetic urine is identical with the yeast plant.

Besides the sugar fungus, however, there is another species which is very commonly met with in acid urine containing albumen, if exposed to the air. This is the *Penicillum glaucum*, the same fungus which is developed in the lactic acid fermentation. This species is represented in the *Illustrations*, Pl. xix, Figs. 1, 4, 5.

The microscopical characters of the fungi in different specimens of urine vary considerably; but, as Dr. Hassall has stated, these differences depend not upon the existence of several distinct species of plants, but rather upon the stage of development which the fungus has reached. Thus, in some specimens of urine, the growth of the fungus is arrested at the sporule stage; in another, not until a thallus is formed; and in a third, it goes on until aerial fructification takes place, and new spores are developed. The degree of acidity of the urine, and the length of time during which it has been exposed to the air, appear to determine, in great measure, the stage of development which the fungus attains. Dutrochet long ago stated that an acid reaction and albumen are necessary for the development of penicillum; but Dr. Hassall, in some more extended

experiments, proved that the fungus often appeared in acid urine which contained no albumen; and I have frequently observed the same point myself.

The penicillum glaucum, as well as the sugar fungus, may be met with in saccharine urine, because all the necessary conditions for its development may be present, namely, exposure to air, an acid liquid, and a certain quantity of nitrogenous matter. Mr. Hoffman of Margate showed that the spores of penicillum would, under favourable circumstances, give rise to the development of the sugar fungus.

From a careful consideration of this question, then, I think we may conclude that, although well defined differences may be made out at certain periods of growth of these fungi, penicillum glaucum and torula cerevisiæ, it must be conceded that there are also forms which could not be distinguished from one another. The large circular sporules of the sugar fungus are distinct enough from those of penicillum glaucum; but oval and circular sporules, which cannot easily be distinguished, are to be obtained under certain circumstances from each plant.

Sarcinæ are little vegetable organisms in the form of little cubes, which are from time to time met with in peculiar cases of obstinate vomiting. They have been observed, however, in other fluids, and occasionally occur in the urine; but the specimens which have fallen under my notice in the urine were smaller than those which I have usually observed in vomit.

Sarcinæ have been met with in the urine by Heller, Dr. Mackay, Dr. Johnsen, and by myself, under circumstances which leave no doubt that this vegetable organism is sometimes developed in urine. I once analysed a specimen of urine containing sarcinæ, which was sent me by my friend Mr. Brown of Lichfield. It was acid; specific gravity, 1018.6.

Analysis 59.

Water	952.8
Solid Matter	47.2
Organic Matter	37.9
Fixed Salts	9.3

The specimen was carefully examined for lactic acid, but not a trace could be detected.

Trichomonas Vaginæ. Donné some years ago described, under the name of trichomonas vaginæ, an organism which he considered to be of an animal nature. It consists of a rounded cell, with vibratile filaments projecting from it, and was found in the urine of females suffering from leucorrhœa. Kölliker and Scanzoni have confirmed Donné's observations, and have detected the trichomonas in the vaginal mucus both of impregnated and of unimpregnated women. I have never been fortunate enough to meet with a specimen of this organism.

Epithelium of the Genito-urinary Passages. The epithelium from the kidney has been already described. It is figured in the *Illustrations*, Pl. xxiv, Figs. 1, 2, 3, 4. The cells from the *ureter* are of the columnar form, and some are spindle-shaped. (*Illustrations*, Plate xxiv, Fig. 5.) In form, and indeed in their general appearance, these cells much resemble those found in scirrhous tumour. Care must be taken not to make the mistake in cases of suspected cancer of the kidney.

Fig. 25.—Epithelium from the bladder. Many of the large cells lie upon the summit of the columnar and caudate cells, and depressions are seen on their under surface. One is seen in the centre of the figure.

The epithelium of the *bladder* varies much in different parts of the organ. In the fundus, there is much columnar epithelium mixed with large oval cells; whereas, in that part termed the trigone, large and slightly flattened cells, with a very distinct nucleus and nucleolus, are most abundant. Columnar epithelium appears to line the mucous follicles, while the scaly lies on the surface of the mucous membrane between them. Various forms of bladder-epithelium are represented in Fig. 25.

The epithelial cells of the *urethra* are, for the most part, of the columnar form; but mixed with this there is also a good deal of scaly epithelium. Towards the orifice, the epithelium is almost entirely of the scaly variety.

The large cells of scaly epithelium, so commonly met with in the urine of females, and derived from the *vagina*, are represented in Fig. 26. They vary, however, much in size and form, and are sometimes very irregular in shape, with uneven ragged edges.

Fig. 26.—Vaginal epithelium from urine.

Spermatozoa. The urine should be examined for spermatozoa as soon as possible after it has been passed, as they often

undergo change rapidly. They may be distinguished with a power of about two hundred diameters; but, unless the eye is familiar with them, it is better to employ one of from four hundred to five hundred.

Spermatozoa often form, with the mucus from the seminal tubules, whitish flocculi, which are suspended in the urine. They may, however, sink to the bottom, forming a deposit invisible to the unaided eye.

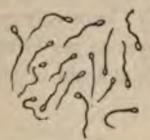

Fig. 27.—Spermatozoa from urine. × 215.

You will sometimes be called upon to examine stains upon linen, or the vaginal mucus, in cases of suspected rape. Such an investigation must be undertaken with the greatest care; and you must not express a positive opinion if you have the slightest doubt as to the nature of the bodies in question; neither should you draw a conclusion from the presence of one body like a spermatozoon, nor from supposed fragments of their bodies. Fragments of cotton or linen sometimes assume forms very like those of spermatozoa. The mucus in which they are suspected to be present may be remoistened with distilled water, without the forms being destroyed. For cases in which spermatozoa were detected, see *Archives of Medicine*, vol. i, pp. 48, 139; *Illustrations*, Pl. xxi, Fig. 2.

Spermatozoa are not uncommonly found in the urine in health. It is only when their appearance is constant, and accompanied with other more important symptoms, that the practitioner is justified in interfering. Let me impress upon you the importance of exercising the greatest caution in these cases; for the mere allusion to the condition may do more harm to the patient's mind than can be counterbalanced by the

good produced by medical treatment. The occasional presence of spermatozoa in urine must not be looked upon, in itself, as evidence of that condition to which the name of *spermatorrhœa* has been applied—a term which I am sorry to employ at all, and which, I think, ought to be abolished altogether.

Vegetable Bodies resembling Spermatozoa. The only structure occurring in urine, or of renal origin, at all liable to be mistaken for spermatozoa, as far as I am aware, are a form of vegetable growth which I have only once met with, in a specimen of urine kindly sent to me by my friend Mr. Masters of Peckham Rye. Mr. C. Roberts of St. George's Hospital has

Fig. 28.—Bodies very closely resembling spermatozoa, but probably of a vegetable nature. The one marked *a* especially resembles a spermatozoon.

taken very careful notes of the case. Some of the bodies in question very closely resembled spermatozoa; but their true nature was ascertained by noticing the characters of many other specimens of the vegetable growth. (Fig. 28.) An account of this case is given in the *Archives of Medicine*, vol. i, p. 251.

Casts of the Uriniferous Tubes.

Casts of the Renal Tubes are seldom found unmixed with other deposits. Frequently they are accompanied with much epithelium, and in many cases blood-globules are present in considerable number. Occasionally, however, we meet with a transparent and scarcely visible deposit, consisting entirely of casts. The connexion between different renal diseases and the presence of casts in the urine has been demonstrated most conclusively by Dr. Johnson; and for extended information on this subject, I must refer you to his well known work *On Diseases of the Kidney*. I shall here only attempt to draw your attention to the microscopical characters of those forms of casts which you are most likely to meet with in examining urine.

Of casts there are several different forms, which are to some extent characteristic of the morbid changes taking place in the structure of the kidney. At the same time, we must not express ourselves confidently, if only one or two casts of a particular kind are found. Thus we may meet with in the deposit of the urine from acute cases, which completely and perhaps rapidly recover, one or two cells containing oil, and one or two casts containing a few oil-globules; but we must not, from the presence of these, be led into the error of concluding that the case is necessarily one of fatty degeneration of the kidney. If, however, there were *numerous* cells and casts containing oil, such an inference would undoubtedly be correct. We must not expect to find in one case *epithelial casts* alone, in another *granular casts* alone, in a third *fatty casts* alone, in a fourth none but *large waxy casts*, and so on; but we must be prepared to meet with several varieties in one case, and must ground our opinion in great measure upon the relative number of any particular kind of cast, and upon the circumstance of other deposits being associated with the casts. For instance, the presence of uric acid crystals and blood-corpuscles would

render it very probable that the case was acute, and of short duration. The absence of these deposits, and the presence of a number of granular or perfectly transparent casts, which can only be seen when the greater part of the light is cut off from the field of the microscope, or the existence of *a number of oil-casts*, render it certain that the case is chronic. The former would indicate that the kidney was becoming small and contracted, while the latter variety of casts occurs when it is often of large size and fatty. Such examples might be multiplied. When we consider how very numerous the secreting tubes of the kidney are, we cannot feel surprised that a different condition should exist in certain cases, in different tubes, at the same time; and, from careful *post mortem* examinations, we know that very different morbid appearances are often seen in different parts of the cortical portion of one kidney. It is not difficult, therefore, to account for the fact of the presence of casts differing much in their diameter and characters in the same specimen of urine.

As has been shown, the cast varies in diameter with that of the canal of the uriniferous tube; but probably, after its formation, it contracts slightly, and in consequence it readily passes from the tube, and escapes into the urine. If the epithelial layer on the basement membrane of the tube be of its ordinary thickness, we shall have a cast of medium size. If the cells be enlarged, and adhere firmly to the basement membrane, the cast will be fine and narrow; while, on the other hand, if the tubes be entirely stripped of epithelium, the basement membrane alone remaining, the diameter of the cast will be considerable. In describing the different varieties of casts, it will be convenient to divide them into three classes, according to their diameter.

You will find numerous figures of the various forms of casts in the *Illustrations of the Urine, Urinary Deposits, and Calculi*, Plates xiv, xv, xvi, xvii, and xviii. These figures have been

traced, from the objects under examination, upon the stone from which the plates have been printed.

The first class of casts, which is by far the largest, will include casts of medium size; the second, those of considerable diameter; and the third will comprehend the smallest casts that are met with.

A. *Casts of medium diameter, about the* 1-700*th of an inch.*
1. Epithelial casts.
2. Pale and slightly granular casts, with or without a little epithelium, or epithelial *débris.*
3. Granular casts, consisting entirely of disintegrated epithelium.
4. Casts containing pus or blood.
5. Casts containing oil.

B. *Casts the diameter of which is about the* 1-500*th of an inch.*
1. Large transparent "waxy casts".
2. Large and darkly granular casts.

C. *Casts the diameter of which is about* 1-1000*th of an inch.*
Small waxy casts.

A. *Casts of Medium Diameter.*

Epithelial Casts are met with in great number in cases of *acute nephritis;* and their presence is generally accompanied with a considerable deposit of uric acid, and also with much free epithelium and epithelial *débris.* These casts often contain many perfect cells of renal epithelium, and not unfrequently blood-globules are entangled in them. (*Illustrations,* Pl. xiv, Fig. 1; Pl. xv, Fig. 1 *a.*)

Besides these casts, however, some of the larger casts, comprehended in the second class, may often be observed; and these have, as Dr. Johnson states, "a wax-like appearance"; or they may be dark and granular, or part of the cast may be so highly granular as to be quite opaque, while in another por-

tion it may be perfectly clear and transparent. Sometimes also a few of the small "waxy casts" may be observed, and rarely a few of the cells may be found to contain well defined oil-globules.

Casts containing Dumb-Bells. In the urine of a patient suffering from cholera, after eighteen hours suppression of urine, I found a trace of albumen, with some very transparent casts entangling dumb-bell crystals of oxalate of lime. (*Illustrations*, Pl. xii, Fig. 1.) Octohedral crystals of oxalate were also present in the urine; but none were to be seen in the casts.

Crystals of triple phosphate and octohedra of oxalate of lime are sometimes met with in casts. Not unfrequently perfectly dark casts are observed. The opaque appearance is due to the presence of urate of soda, which is proved by the fact of the casts becoming perfectly transparent upon applying a gentle heat to the slide upon which the specimen is placed. (*Illustrations*, Pl. xiv, Fig. 4.) These casts appear white by reflected light.

In *chronic nephritis*, a considerable number of "granular epithelial casts", of medium diameter, will be present in the early stage of the disease. In the second stage, the granular casts become more abundant, and often form a white deposit at the bottom of the vessel.

Dr. Johnson says that, in the third stage, there may be an abundant deposit composed of granular casts and disintegrated epithelium; or secondly, the granular casts may be mixed with large waxy casts, with a sharp and well defined outline; or thirdly, the waxy casts may be in small number, and mixed with a few granular casts and disintegrated epithelium. Casts from a case of chronic nephritis are represented in the *Illustrations*, Pl. xv, Fig. 2; Pl. xvii.

Casts containing Oil. In that condition of the kidney termed "fatty degeneration", the pale albuminous urine frequently contains a number of casts which appear to be made

up of oil-globules, or composed of cells containing oil. In adults recovering from acute nephritis, it is not uncommon to find a few oil-particles in the casts, and cells crammed with small oil-globules floating in the surrounding fluid; but at the same time, if there be a greater number of granular or epithelial casts, the presence of the oil need not excite any apprehension for the patient's safety. If, however, on the other hand, the oil casts increase while the other casts diminish in number, we should probably find that the case would become one of confirmed fatty degeneration. The composition of the oil in these cases has been alluded to. (See *Illustrations*, Pl. xviii, Figs. 1 and 2.)

Fat-Cells. Besides the occurrence of fatty matter in casts, and in cells entangled in casts, it is very commonly met with in cells, in the urine; and occasionally these cells are present without any casts. They consist usually of epithelial cells of the kidney, enlarged and gorged with oil. Sometimes they contain a few oil-globules, which are well defined, and are seen to be distinct from each other; while, in other instances, the globules are very minute, and so crowded together that the cell appears perfectly opaque and dark, resembling the so-called inflammatory globules. Although I use the term *cell*, it is not possible in many cases to demonstrate the existence of a *cell-wall*. Occasionally, cells containing oil-globules may be derived from some other part of the mucous surface of the urinary passages. I have seen epithelial cells, and collections of oil-globules which have been removed from the membranous portion of the urethra. It is therefore important to bear in mind that cells containing oil-globules are occasionally met with in cases where the kidneys are not diseased.

Casts containing Blood-Globules are not unfrequently met with in the deposit of the urine in acute nephritis. They are usually of medium size, and often contain a certain quantity of epithelium. (*Illustrations*, Pl. xv, Fig. 1 *b*.)

Pus is very rarely found in casts, although some cells agree-

ing in character with the pus-globule, in the development of two or three little circular bodies in the centre when acted on by acetic acid, are not unfrequently observed. Cases in which the urine exhibits these characters are generally acute, and terminate fatally in a short time. A beautiful specimen of the urinary deposit in one of these rapidly fatal cases is represented in Plate xvi of the *Illustrations.* At the same time, I have seen two or three instances occurring in children where these casts and cells were most abundant, which have completely recovered.

B. *Casts of considerable Diameter.*

The *large waxy casts*, of about the one-five-hundredth of an inch in diameter, are obviously derived from tubes which have been entirely stripped of epithelium; for under no other circumstances could casts of this diameter be formed. They are often met with in small quantity in the urine of acute desquamative nephritis; but when present in very large quantity, a condition of kidney to which Dr. Johnson has given the name of "waxy degeneration", from the peculiar glistening appearance of the substance with which the tubes are filled, is present. Large waxy casts are represented in the *Illustrations*, Pl. xvi, *a* and *b*.

In some cases, at least, it is certain that these casts of large diameter are formed in the lower part of the straight portions of the uriniferous tubes where these are very wide. Often it is evident that the material is deposited in successive layers. In Fig. 29, at *b*, two such casts are represented. Although in some cases the convoluted portion of the uriniferous tube is wide enough to admit of the formation of one of these large waxy casts, I have never seen an instance where the tubes between the cortical and medullary portion of the kidney were large enough to permit them to pass through. There is evidence that much of the material is in some cases deposited in the

lower straight portion of the uriniferous tubes. (*Illustrations*, p. 39; *Archives of Medicine*, vol. i, p. 303.)

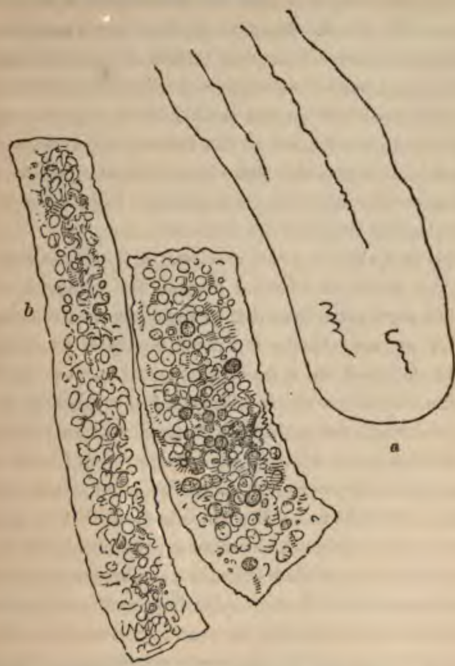

Fig. 29.—*a*. Large transparent waxy cast. The other two figures, *b*, represent casts which have received a deposit upon their outer surface during their descent from the kidney, probably in the straight portion of the uriniferous tubes. × 215.

C. *Casts of small Diameter.*

The small waxy casts, on the other hand, are derived from tubes in which the epithelial lining is entire, and in which there appears no tendency for desquamation to take place—a condition to which the name of "*non-desquamative nephritis*"

has been applied. The urine is either found to contain no deposit whatever, although albuminous, or only some of the small waxy casts, not more than one-thousandth of an inch in diameter, can be found. In some of these cases, symptoms of blood-poisoning come on, and a rapidly fatal result occurs. The casts have a perfectly smooth and glistening surface, and present in the microscope the same general appearance as a piece of the elastic lamina of the cornea. (*Illustrations*, Pl. xiv, Fig. 6.) It is probable that some of these very fine casts come from contracted tubes, and perhaps from tubes which have not attained their full development.

Of Casts in a clinical point of view. It is not too much to say that the treatment of renal disease has advanced within the last few years more than that of any other class of diseases. Frequently we are able to say most decidedly what course should be followed in a given case; and we can indicate exactly the conditions which will retard the progress of the malady, and warn the patient of those which would certainly hasten the extension of disease. I do not think I have at all exaggerated the improvement which has taken place in this department of medicine; and when we reflect that we possess more positive knowledge of the anatomy and physiology of the kidney, and that its morbid changes have been more successfully investigated than those of other important organs, we can scarcely help attributing the improved treatment to our increased knowledge, and we have every encouragement to hope that ere long a similar result will be seen as distinctly in other branches of medicine. I am quite sure that many patients with chronic renal disease are now kept alive, and even enjoy life, for many years longer than was possible at a time when the exact nature of their malady was not understood, and when the treatment considered right was of a kind which no one, knowing anything of the nature of the changes taking place, would now think of adopting.

I do not propose to discuss the treatment of these diseases

in the present course of lectures; but let me say that, as a general rule, it is very simple; and, if you feel satisfied of the nature of the disease, you will in many cases at once determine the right course of treatment to be pursued, especially if you consider carefully the physiology and pathology of the organ. But let me warn you of the danger of making a diagnosis too hastily. If you do not feel quite sure you are right in the opinion you have formed of the case, do not act as if the diagnosis was decided; for, although the treatment is simple, the harm resulting from acting upon a wrong view may be irreparable. The application of cold where warmth is required, the administration of stimulating diuretics where the kidneys require rest, the abstraction of blood where the patient has but too little for the requirements of his system, may be carried out to the detriment of the patient, upon a false view of the nature of the disease. Your observation of these cases cannot be too extended, and you should especially study the history of the disease as recorded in many published cases. I hope, from these observations, you will not think I undervalue the study of the treatment of disease, and infer that I only attach importance to the diagnosis of the case; but will only conclude, what I believe cannot be impressed upon you too strongly—that important as a knowledge of various plans of treatment, and of the action of various drugs, undoubtedly is, it is of no real use—it is even worse than useless—unless the practitioner possess that fundamental knowledge of the actual changes taking place in the various organs of the body in health which will alone enable him to arrive at a correct conclusion as to the nature of a case of disease.*

In the next lecture, we shall consider the characters of the second class of deposits, which are characterised by the formation of a bulky, dense, opaque, and often abundant precipitate, which sinks to the bottom of the vessel, leaving a clear or more

* As to the treatment of diseases of the kidney, the works of Dr. George Johnson, Dr. Basham, and Dr. Owen Rees, should be consulted.

or less opaque supernatant fluid. The most important substances occurring in this second class are deposits of *pus*, *phosphates*, and *urates* of *soda* and *ammonia*; and in certain cases, by examination with the unaided eye, it is quite impossible to decide which of these deposits is present. By the application, however, of a few simple tests, or by submitting a specimen to microscopical examination, we are enabled to ascertain with certainty which of the three deposits is present.

LECTURE X.

Urine in Disease. III. Of Dense and Opaque Deposits. *Pus. Urates. Phosphates, general characters. Urates. Urinary Deposits associated with Urates. Urates in Urine, without forming a Deposit: Albumen present. Analyses of Deposits of Urates. Pus. Characters of the Urine. Tests for Pus. Of the Presence of Pus in Urine, in a Clinical Point of View. Earthy Phosphates. Triple or Ammoniaco-Magnesian Phosphate. Tests. Phosphate of Lime. Phosphate of Lime, in the form of Spherules and Small Dumb-Bells. Peculiar Form of Phosphate, usually regarded as consisting of Triple Phosphate. On the Crystalline Form of Phosphate of Lime.*

III.—Second Class of Urinary Deposits.

Gentlemen,—We now come to the consideration of the second class of deposits, which forms a bulky, dense, opaque, and often abundant precipitate, which sinks to the bottom of the vessel, leaving a perfectly clear, or more or less turbid, supernatant fluid.

Pus, Urates, Phosphates. The most important deposits of this class are those consisting of *urate of soda*, *pus*, and *earthy phosphate*. To the practitioner these three deposits are especially interesting; and, as their presence in the urine is characteristic of important morbid conditions differing widely in their results from each other, while the appearance of the deposits to the naked eye is very similar, it is a matter of great importance that the practitioner should be able to distinguish them from each other with certainty, and at the same time with facility. Before entering, therefore, upon a

detailed description of these bodies, let me draw your attention to an exceedingly simple method of distinguishing them. Let the clear supernatant fluid be poured off, and a little of the deposit be transferred to a test-tube. Upon the addition of about half the bulk of solution of potash, one of the three following points will be noted:—*No change* will be produced, in which case the deposit consists entirely of *phosphate*. Secondly, the mixture will become *clear*, and very *stringy* or *viscid*, so that it cannot be poured from the test-tube in drops. In this case, we may be certain that the deposit consists of *pus*. Thirdly, the solution of potash may cause the mixture to become clear, but not viscid, in which case *urate of soda and ammonia* enter very largely into the composition of the deposit. Often liquor potassæ gelatinises the mixture, but does not render it clear, in which case it is probable that both *pus* and *phosphates* are present. In any of the above instances, our conclusion as to the nature of the substance should be confirmed by some of the tests presently to be mentioned, and by microscopical examination.

Urates. From the researches of Heintz (*Lehrbuch der Zoochemie*), it appears that this deposit, usually termed *urate of ammonia*, really consists principally of *urate of soda* and *urate of ammonia*, with small quantities *of urates of lime and magnesia*. It forms the most common urinary deposit. A small quantity of urate is held in solution in healthy urine; and, in slight derangement of certain chemical changes going on in the body, it is often secreted in such quantity as to be deposited soon after the urine is passed. Urate of ammonia, when artificially prepared, crystallises in delicate needles; but in this form it is never found in the urine; for, as Dr. Bence Jones has shown, the slightest trace of chloride of sodium causes the salt to assume an amorphous character, and increases the solubility of the urate by one-half. Urate of soda is sometimes found in the urine, forming globular masses, from different parts of which sharp spikes of uric acid project.

In the urine of children, it is very frequently met with in the form of small spherical globules very like the crystals of carbonate of lime from horses' urine; and these sometimes occur in the adult. Some of the largest spherules I ever saw

Fig. 30.—Urate of soda crystallised in spherules, from healthy urine concentrated by evaporation.

are figured in the *Archives of Medicine*, vol. i, p. 249. See also *Illustrations*, Plate VIII, Figs. 2, 5, and 6. In Fig. 30, some spherules of urate of soda, obtained by concentrating healthy urine, are represented.

Urate of soda is not very soluble in cold, but is readily dissolved by a small quantity of warm water; from which, however, it is deposited as the solution cools. It is readily dissolved by alkalies, and also by solutions of alkaline carbonates and phosphates. Pure urate of soda crystallises in small acicular crystals, which are more or less aggregated together. In this form, it is found in the pasty deposits forming chalk-stones in cases of gout. This thick deposit contains much water. In one specimen I examined, the solid matter only amounted to 29.9 per cent., and consisted chiefly of urate of soda.

Deposits of urate of soda vary very much in colour, sometimes occurring as the white or pale "lateritious deposit" or "nut-brown sediment"; while in other cases the deposit has a pink, brown, or even dark reddish colour. The amorphous urate is repre-

sented in the *Illustrations*, Plate VIII, Fig. 1. Upon the addition of moderately strong acids, the deposit of urate is slowly dissolved; but in a short time a slight granular precipitate may be observed, which, upon microscopical examination, is found to consist of rhomboidal crystals of uric acid. It is not uncommon to meet with specimens of urate deposit which become decomposed after the urine has left the bladder, when numerous crystals of uric acid are deposited. If urate of ammonia be treated with nitric acid, and, after evaporation to dryness, ammonia be added, the beautiful purple colour, owing to the formation of murexide, is produced. This reaction will come under our notice when we discuss the characters of uric acid. Rubbed with caustic lime, a perceptible odour of ammonia is evolved.

Urinary Deposits associated with Urates. This deposit of urates is more frequently accompanied with oxalate of lime than with any other salt. It has been shown that urates may be readily decomposed into oxalates after the urine has been passed. The crystals of oxalate are often so minute as readily to escape detection in the abundant deposit of urate, unless the latter be dissolved by the addition of a few drops of solution of potash. *Triple phosphate* is not unfrequently met with amongst the urate, and occasionally a deposit of phosphate of lime has been observed, in which case the reaction of the urine will be neutral or even alkaline. Urate of soda is occasionally the cause of the dark granular appearance exhibited by certain casts, as may be proved by slightly warming the deposit, and then examining it with the microscope, when the casts will be found to have become clear.

Urates present without forming a Deposit: Albumen present. Often the urate remains suspended in the urine without forming a visible deposit, and produces a curious opalescence. Sometimes the urine resembles in appearance the so-called chylous urine; but its true nature is readily made out by the application of some of the tests above referred to. (See also

Chylous Urine.) If albumen be present in urine containing urates, it will not become clear by heat, or rather, it will at first clear, but soon become turbid again, in consequence of the precipitation of the albumen. With a little care, however, in applying the heat, the upper stratum of urine in the test-tube may be made hot enough to coagulate the albumen, the middle stratum being *cleared* by the solution of the urate without the albumen being thrown down, while in the bottom of the tube the deposit remains unchanged. In performing this experiment, you must hold the test-tube at its lower part.

Analyses of Deposits of Urates. The urine of a child suffering from scarlatina, with delirium and unconsciousness, contained an abundant deposit of urates. It was acid; specific gravity, 1025.

Analysis 60.

Water	932.2	
Solid matter	67.8	100·
Organic matter . .	59.03	87.07
Fixed salts . . .	8.77	12.93
Uric acid . . .	1.19	1.75

In a deposit which was composed of rounded globules, with small sharp spicules projecting from them (uric acid), I found the following constituents: phosphate of lime, urate of soda, and other urates. I found a considerable quantity of these spherules in the urine of a man suffering from pneumonia, and they had the following chemical characters. They exhibited distinct evidence of the presence of uric acid by the murexide test. They were soluble in boiling potash; and when, to the alkaline solution, excess of hydrochloric acid was added, well defined crystals of uric acid were formed. Upon exposure to a red heat, an odour like that of burnt horn was exhaled; and, after decarbonisation, a moderate quantity of a white ash remained, which dissolved in acids with effervescence; and from the acetic acid solution a precipitate was thrown down, upon

the addition of oxalate of ammonia. I conclude, therefore, that urate of lime entered into the formation of these crystals. The quantity of crystals at my disposal was far too small to make a quantitative analysis.

Pus. The next deposit to be considered is pus. Pus is not found in healthy urine, although it is very frequently met with in the urine of persons past the middle period of life whose general health is good. The changes by which a healthy mucous membrane becomes converted into a pus-forming surface are not yet well understood; but certain it is that such a change may take place without the essential purposes of the mucous membrane being interfered with. The portion of the genito-urinary mucous membrane most frequently affected in this way is undoubtedly the urethra, and I believe, next to this, that of the ureters and pelvis of the kidney; while the functions of the bladder, as a general rule, become seriously deranged before its mucous membrane forms much pus. To this last statement there are, however, exceptions. That an enormous quantity of pus may be formed in the pelvis of the kidney and in the infundibula, without seriously interfering with the general health of the patient, is a fact which has been confirmed by many cases. One I particularly recollect—a woman in the hospital, about five or six years ago, under Dr. Todd, who for upwards of a twelvemonth had been passing urine a fourth part of the bulk of which consisted of pus. This patient had not suffered in nutrition or in general health, and she had gone through her occupation as servant as usual.

Much pus is often formed upon the mucous membrane of the vagina, which will, of course, be found in the urine, accompanied with some of the large cells of vaginal epithelium. The urine of men after the age of forty often contains a greater or less number of pus-corpuscles—a fact of which I was not aware until I had subjected the urine of a great number of hospital patients indiscriminately to examination. In private

practice, the same point is noticed very frequently. It is, indeed, more common to find a few pus-corpuscles in the urine after this period of life, than to find it free from them. This fact is important, and shows that the existence of pus in the urine must not, *per se*, be regarded as evidence of serious disease.

Characters of the Urine. Pus generally forms an opaque cream-coloured deposit, which sinks to the bottom of the vessel, the supernatant fluid being generally slightly turbid, from the presence of a few pus-globules. The deposit, however, readily diffuses itself again by agitation. The urine will always be found to contain a little albumen derived from the liquor puris. If, however, the albumen exist in large quantity, it is probably derived from some other source. If the urine be alkaline, the pus is no longer present as a cream-coloured deposit, but exists as a gelatinous or stringy mass, which adheres firmly to the sides of the vessel containing it. It is to this glairy mass that the term mucus has been, and even still is, carelessly applied. The viscid, glairy, mucus-like deposit arises from the carbonate of ammonia, set free by the decomposition of urea, reacting on the pus-globules in a manner similar to that in which potash behaves. The microscopical characters of the pus-corpuscle are clear and well defined.

Tests for Pus. The tests, then, which may be relied upon for detecting the presence of pus in urine, are, the addition of solution of potash to the deposit; and of nitric acid, and the application of heat to a portion of the supernatant fluid, in order to detect the presence of albumen. Cases from time to time come under notice in which the amount of albumen is very small; but still the quantity may appear to us to be in too large a proportion to the pus-cells present, to belong solely to the liquor puris. In such a case, we should be led to suspect kidney-disease, and should therefore very carefully search the deposit for casts of the tubes.

Microscopical Characters of Pus. In those cases in which

the pus is in too small quantity to be detected by chemical tests, we must rely upon the microscopical examination of the deposit, and the development of two or three small round bodies in the centre of each pus-globule upon the addition of a

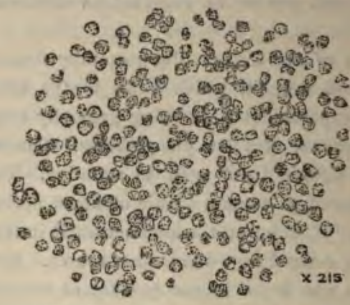

Fig. 31.—Pus corpuscles from urine.

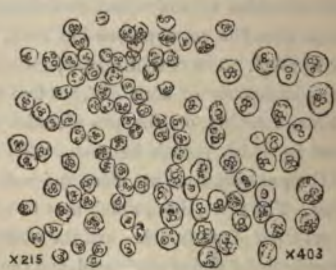

Fig. 32.—Pus corpuscles acted upon by acetic acid.

drop of acetic acid. Pus globules always have a granulated appearance in the microscope, and, when fresh, exhibit, under ordinary magnifying powers, no well defined nucleus ; the outline is usually distinct and circular, but it is finely crenated. Upon the addition of acetic acid, the globule increases somewhat in size, becomes spherical, owing to endosmosis, with a smooth faint outline ; and from one to four nearly circular bodies are developed in the centre of each. (Fig. 32.)

Of the Presence of Pus in Urine in a clinical point of view. You will have gathered from what I have already said, that the presence of a few pus-corpuscles in urine is a fact which need not excite our alarm; that the mucous membrane of the urethra in many cases becomes affected in a slight degree in the same manner as some other mucous membranes; and that pus-corpuscles are formed in small number upon its surface, without causing any material impairment of structure or derangement of function. In the urine of the female, it is very common to find small quantities of pus which are derived from the mucous membrane of the vagina. When, however, pus is found in the urine in sufficient quantity to form a deposit visible to the naked eye, it should excite our attention. The fact will probably bear in a very important manner upon the diagnosis of the case. Pus may be derived from any part of the genito-urinary mucous membrane; from the surface of the *urethra;* from the *prostate;* from the *bladder*, or from the *follicles of the mucous membrane* in these parts; from the *ureters;* from the *pelvis of the kidney*, or from the *secreting structure of the organ.* The pus may also come from an *abscess* opening upon any part of the surface of this mucous membrane.

It is often difficult to form an opinion as to the exact seat of formation of the pus; and it must be obvious that we ought never to come to a decision on such a point until we have accurately weighed all the evidence that a careful investigation of the case will afford. Microscopical examination will give us important help; but we must not rely upon this, or indeed upon any single mode of investigation. The question is an extensive one, and I shall only refer to one or two points connected with the evidence deduced from microscopical examination, as you are quite familiar with the nature of the other evidence to be obtained in such cases. You may often form some idea of the locality from which the pus has been derived by examining attentively the characters of any epithelial cells which

may be mixed with it. (Lecture IX.) When pus is derived from the bladder, it generally contains crystals of triple phosphate, and granules or small spherules of earthy phosphate mixed with it; and the symptoms of the case will generally enable you to decide if the pus is formed in this viscus. Large quantities of pus may escape from the bladder for a number of years. I know of one gentleman who has passed pus in considerable quantity from the bladder during a period of twenty-five years. The suppuration of the bladder may be due to gonorrhœa, to gout, and to a state of mucous membrane which is termed catarrh of the bladder. When the pelvis of the kidney is dilated and sacculated (a form of pyelitis), the quantity of pus passed in the urine is often enormous; and this may last for years, until the kidney becomes a mere pus-forming cyst, which, in favourable cases, gradually contracts; the formation of pus ceases; the cyst slowly wastes; and the patient perfectly recovers; the work of the two kidneys being performed by the remaining one, which has gradually undergone an increase in size corresponding to the increased work it has been called upon to perform. When pus is derived from the pelvis of the kidney, the earthy phosphates are often completely absent. There is a chronic state of ulceration of the ureters and pelvis of the kidney and bladder, in which pus is formed in considerable quantity, leading to the most distressing symptoms. Pus may depend upon the existence of old stricture.

Abscesses form in the kidney as in other organs; and, after the abscess has burst, pus makes its way into the urine. The inflammation of the mucous membrane of the kidney often extends upwards from the bladder. The presence of a calculus in the kidney, in the ureter, or in the bladder, may set up inflammation which may go on to the formation of pus. A very small calculus will sometimes excite great irritation in the kidney, so that both pus and blood are voided in the urine.

Pus may be derived from a sloughing process going on in the

kidney. Sometimes a portion of the organ sloughs off entire in these cases. My friend Mr. Newham, of Bury St. Edmunds, sent me, a short time since, a piece of kidney which had sloughed off, and was passed with much pus in the urine. Pus may also depend upon the presence of cancer in the kidney, or upon tubercle developed in the same situation.

Pus may come from an acute affection of the uriniferous tubes, and the corpuscles will be found free in the urine, and entangled in considerable number in casts. These cases are often very rapidly fatal. (See *Illustrations*, Plate XVI.)

Earthy Phosphates. The earthy phosphates soluble in acids, but insoluble in water and alkaline solutions, which are most commonly met with as deposits in urine, are, the ordinary *triple* or *ammoniaco-magnesian phosphate*, or the *phosphate of ammonia and magnesia;* and the *phosphate of lime.*

Triple or *Ammoniaco-Magnesian Phosphate.* The triple phosphate crystallises in two or three different forms. The most common form is that of the triangular prism with obliquely truncated ends; but these are sometimes complicated by the bevelling of the terminal edges. Not unfrequently the crystal is found much reduced in length, and the truncated extremities become so approximated as to give the appearance of a

Fig. 83.—Crystals of triple phosphate and small globules of phosphate of lime, from urine.

square the opposite angles of which are connected by straight lines; and thus an appearance very closely resembling that of an octohedral crystal of oxalate of lime is produced. Crystals of this salt are very frequently deposited from acid urine; and,

when clear and unmixed with other deposits, they form a most beautiful microscopic object.

Tests. If ammonia be added to fresh urine, or to a solution of phosphate of soda and sulphate of magnesia, ammoniaco-magnesian phosphate is precipitated in the form of beautiful stellate crystals, as I mentioned when speaking of healthy urine. Besides these forms, Dr. Golding Bird describes two others in the form of simple stellæ, often so crowded as to appear like rosettes and penniform crystals, which latter are very rare.

Ammoniaco-magnesian phosphate is slightly soluble in pure water, particularly if it contain carbonic acid. It is insoluble in solutions of ammoniacal salts. Heated in the blowpipe flame, ammoniaco-magnesian phosphate evolves a disagreeable odour of ammonia, and afterwards fuses, producing a whitish enamel. If the phosphate of magnesia thus formed be dissolved in a little dilute acid, the triple salt may be again formed upon the addition of ammonia. The presence of phosphoric acid can readily be proved by the appropriate tests.

Deposits associated with Triple Phosphate. Ammoniaco-magnesian phosphate seldom occurs alone as a urinary deposit. Its presence is often associated with urate of ammonia, and sometimes with uric acid. I have also observed crystals of oxalate of lime mixed with those of triple phosphate. In highly alkaline urine, it is usually accompanied with phosphate of lime.

Phosphate of Lime occurs as minute granules, as small spherical masses, and it may also be noticed in the form of minute dumb-bells—an appearance probably due to the adhesion of two little spherules, which afterwards become coated with a fresh deposit of the phosphate. Phosphate of lime is usually associated with the triple salt, and is deposited from alkaline urine. In cases of disease of the bladder in which the urea becomes very rapidly decomposed into carbonate of ammonia, much amorphous phosphate of lime and triple phosphate are precipitated. It must not, however, be sup-

posed that highly alkaline urine *necessarily contains* a very large *excess* of earthy phosphate; for often an excessive quantity of the salts have been found dissolved in acid urine. When the secretion is alkaline, the phosphates are precipitated, and become visible to the naked eye as a deposit. Phosphate of lime dissolves in strong acids without effervescence; and from this solution is precipitated in an amorphous form, upon the addition of ammonia. The salt is infusible before the blowpipe, unless mixed with triple phosphate; and its fusibility increases according to the quantity of the latter salt present. The lime may be recognised in the usual way by the addition of a solution of oxalate of ammonia to a solution of the salt in acetic acid.

Phosphate of lime is soluble in albumen; indeed, it is by reason of its solubility in this substance that the phosphate of lime formed by the action of phosphoric acid on the egg-shell becomes applied to the formation of the osseous system of the embryo chick. Mucus also is a solvent of this salt, and from the mucus of the gall-bladder a considerable quantity is deposited as decomposition proceeds. (Fig. 34.)

Phosphate of Lime in the Form of Spherules and small Dumb-Bells. Deposits of phosphate of lime are generally granular; but after a deposit has been allowed to stand for

34

35

Fig. 34.—Dumb-bell crystals of phosphate of lime from the gall-bladder.
Fig. 35.—Dumb-bell crystals of phosphate of lime from urine.

some days, little spherules are very frequently found, and it is also not uncommon to meet with small dumb-bell crystals.

Crystals of the latter character are very often deposited in decomposing mucus, derived from several mucous surfaces, as well as in that of the urinary mucous membrane. Some of the largest of these dumb-bell crystals of phosphate of lime are represented in Fig. 35. They were found in the urine of a patient suffering from continued fever, under the care of Mr. Carver of Cambridge, who sent me the specimen.

A peculiar form of deposit of earthy phosphate is represented in Fig. 36. It consisted partly of phosphate of lime,

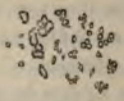

Fig. 36.—Unusual form of triple phosphate, and phosphate of lime. From the urine of a gentleman suffering from dyspepsia. × 215.

and partly of triple phosphate. There were no true crystals, neither was the deposit in a pulverulent form. The little angular masses represented were the only bodies found in this peculiar deposit.

Peculiar Form of Phosphate, usually regarded as consisting of Triple Phosphate. A phosphate of the form represented in Fig. 37 is not uncommonly found in urine. I have not been

Fig. 37.—More uncommon form of phosphate, usually regarded as triple phosphate, crystallised differently from Fig. 33, which represents its usual form. These are probably the "simple stellæ" of Dr. Golding Bird's "neutral salt."

able to connect its presence with any special state of the system, nor to ascertain the conditions upon which its deposition depends. It is very frequently associated with oxalate of lime, and occurs in acid urine. A considerable quantity of these crystals were deposited from the urine of a man who had a rough oval calculus, composed of oxalate of lime, impacted in the ureter. The case is given in Dr. Todd's *Clinical Lectures*, 2nd ed., p. 562. They were examined as follows:—

(March 1851). "The deposit from about a pint and a half of urine was well washed with water and alcohol, and filtered; it was then dried, incinerated, and decarbonised. The form of the crystals had not been materially altered by the ignition; for, when examined by the microscope, scarcely any change could be observed.

"A portion of the decarbonised crystals were dissolved in dilute hydrochloric acid (they were only very slowly soluble in acetic acid).

"1. Ammonia and potash produced gelatinous precipitates.

"2. Chloride of barium caused a slight precipitate in the acid solution; but, upon the addition of excess of ammonia, a bulky white precipitate occurred.

"3. After the addition of ammonia and resolution of the precipitate by acetic acid, oxalate of ammonia was added, and a white granular precipitate was produced.

"4. After the addition of nitrate of cobalt and ignition in the blowpipe flame, a beautiful blue was given to the mass." This reaction usually occurs with phosphate of lime, as well as with alumina. These crystals then consisted principally of phosphate of lime.

In another case which I examined, the crystals also appeared to consist principally of phosphate of lime. They were dissolved in nitric acid, and ammonia added. An *amorphous* precipitate occurred; but no crystals were formed after the lapse of some hours. After separation of the lime by oxalate of ammonia, and filtration, ammonia and phosphate of soda were added. A

very few crystals of triple phosphate formed after the lapse of some time. There was an abundant precipitate of oxalate of lime.

In other cases, a phosphate of magnesia seemed to predominate. From not being able to make satisfactory quantitative analyses, owing to the small quantity of the salt obtained for examination, I was unable to determine the exact nature of these crystals. They are, as I before said, found in acid urine; and phosphoric acid, lime, and magnesia, are present. These are probably the crystals which were regarded by the late Dr. Golding Bird as "small calculous concretions and simple stellæ of the neutral salt".

On the Crystalline Form of Phosphate of Lime. Dr. Hassall, in an interesting paper published in the *Proceedings* of the Royal Society, vol. x, p. 281, Jan. 1860, has stated that phosphate of lime is very commonly found in deposits from human urine in a crystalline form. He gives quantitative analyses of four specimens of deposit which contained the phosphates in the following proportions:—

Bibasic phosphate of magnesia .	0.15	0.47	4.30	
Bibasic phosphate of lime . .	1.85	6.18	5.41	1.96
	2.00	6.65	9.71	

Dr. Hassall states that Dr. Golding Bird's "penniform" crystals of ammoniaco-magnesian phosphate are really a modification of those of phosphate of lime. The crystals represented by Dr. Hassall in Figure 1 appear to be similar crystals to those I have delineated in Fig. 35, the chemical composition of which I have alluded to. See also *Illustrations*, Plate XXII, Figs. 1, 2, 3, 4, 5, 6. I have never obtained these crystals in sufficient quantity for a quantitative examination, but have examined several specimens qualitatively, and have found that they contained ammoniaco-magnesian phosphate, as well as phosphate of lime. The latter not being crystalline when alone, was regarded as the less important constituent of the

crystals, while the form and crystalline properties of the salt were referred to the triple phosphate. If, however, the crystalline form of the pure salt in Dr. Hassall's fourth analysis is represented in his Fig. 1, the composition of these crystals is determined, and the phosphate of magnesia obtained in some of my examinations must be regarded as an impurity, and not as a necessary constituent.

Dr. Hassall, in the paper above referred to, goes so far as to say "that phosphate of lime, in the form of crystals, is of much more frequent occurrence in human urine than the triple phosphate;" and that "granular calcareous deposits are much more rare than the crystalline." Now, in these statements, I think he will find that few observers will agree with him; for that the ordinary crystals so commonly present in the urine, and usually termed triple phosphate, are actually composed of that salt, there cannot be the smallest question. Crystals of exactly similar form may be readily obtained artificially. The salt is easily obtained from any urine by precipitation by ammonia, and is often found very nearly pure, in large quantity, in urinary calculi. That these crystals, so familiar to every one, are more frequently met with than any other form of earthy phosphate, crystalline or non-crystalline, I conclude no one will deny. That phosphate of lime often occurs in urine in an amorphous form, and not unfrequently in little spherules and small dumb-bells, as have been figured; and that, when thrown down from its solutions, the deposit is amorphous; and that in calculi it is amorphous,—are facts generally assented to, and they have been repeatedly confirmed. It seems to me that these circumstances militate against the conclusion arrived at by Dr. Hassall as to the relative frequency of the crystalline forms of phosphate of lime and triple phosphate.

It is important to bear in mind that in many cases, when large quantities of phosphate of lime are excreted in the urine, the salt is dissolved, and does not form a deposit.

You must not, therefore, from the absence of a deposit, conclude that these salts are not excreted in abnormal quantity. The various forms of phosphate which have been described often occur in very small proportion, so that the observer would probably expect to find them in the third class of urinary deposits; but I have thought it better to describe them here, with the other salts of this kind, than to postpone their consideration.

LECTURE XI.

URINE IN DISEASE. VI. GRANULAR AND CRYSTALLINE DEPOSITS, SMALL IN QUANTITY. *Uric Acid. Of the Crystalline Forms of Uric Acid. Tests for Uric Acid. Of the Clinical Importance of Uric Acid. Oxalate of Lime. Octohedral Crystals of Oxalate of Lime. Form and Composition of the Crystals. Dumb-Bell Crystals of Oxalate of Lime. Of the Formation of the Dumb-Bell Crystals. Of the Conditions under which the Dumb-Bell Crystals occur. Deposits often associated with Oxalate of Lime. Of the Examination of Deposits of Oxalate of Lime in the Microscope, aad of their Chemical Characters. Of Oxalate of Lime in a Clinical Point of View. Cystine. Analyses of Urine containing Cystine. Carbonate of Lime. Blood-Corpuscles. Chemical Characters of Urine containing Blood. Of Blood in the Urine clinically. Circular Sporules closely resembling Blood-Corpuscles.* BODIES VERY RARELY MET WITH IN URINE, AND SUBSTANCES OF A DOUBTFUL NATURE. *Cancer-Cells. Tubercle-Corpuscles. Spherical Cells containing Nuclei and Granular Matter. Small Organic Globules.* ENTOZOA. *Echinococci. Diplosoma Crenata (Farre). Strongylus Gigas. Larvæ of the Blow-fly. Acari.*

IV.—THIRD CLASS OF URINARY DEPOSITS.

Uric or Lithic Acid. Among the deposits which I have arranged in a third class, and which are characterised by their small bulk, by their crystalline or granular appearance, as well as by their density, may be mentioned, in the first place, *uric* or *lithic* acid—a substance which has before been brought under notice as a constituent of healthy urine, and of which the chemical properties and general characters were then briefly

referred to. In this place, I wish to draw your attention to the various crystalline forms this substance assumes in different specimens of urine, and to the most simple methods of recognising its presence when its true nature cannot be positively determined by its crystalline characters. It forms a most important deposit, and perhaps is more frequently met with than any other form of urinary sediment, with the exception of the urates; and, although there seems reason to believe that, as chemico-pathological investigation advances, we shall no longer regard the presence of this, or indeed of any other substance, in the urine, as evidence of the existence of a particular diathesis, its presence in many cases, especially when the deposit occurs very frequently and in considerable quantity, affords an indication that the chemical changes in the organism are more or less modified.

The quantity of uric acid in the urine depends to a certain extent on the activity of the skin; and, as a general rule, when there is profuse cutaneous perspiration, the amount of uric acid in the urine will be found to diminish. If, on the other hand, the function of the skin be in any way impaired, or perspiration be impeded by cold, a considerable increase in the quantity of uric acid will take place. Marcet found that the amount of uric acid diminished after severe perspiration; and Fourcroy noticed more uric acid in the urine of a man in winter than in summer. In this way may be explained the presence of the large quantity of uric acid in the urine of persons affected with acute dropsy, or dropsy after scarlatina; and it seems probable that the frequency with which these deposits are met with in the urine of persons affected with skin-diseases (especially eczema and lepra) may be due simply to the impaired function of the skin. In increased muscular exertion accompanied with imperfect respiratory action, uric acid occurs in abnormal quantity. It is present as a deposit in very many cases of chorea. It should, however, be borne in mind that uric acid is often dissolved in the urine as a

urate at the time it is passed, but is afterwards precipitated, being probably separated from its combination with soda (urate of soda) by the process of acid fermentation.

Of the Crystalline Forms of Uric Acid. In the great variety of crystalline forms which uric acid assumes, it is not surpassed by any other substance. Its true primitive form is not easily determined; but that in which it appears most constantly is the rhombic, although in many instances this occurs with two of its angles rounded. From its salts, however, the acid may be separated in rhombic tablets, or in six-sided plates, somewhat resembling crystals of cystine, by the addition of acetic, nitric, or hydrochloric acid.

The form of the crystal is much affected by the strength of the acid which is added. This subject has been investigated by Dr. A. E. Sansom (*Transactions* of the Medical Society of King's College, London, Winter Session, 1856-57, p. 128). The following are the results:—

Acid in small quantity .	Crystals regular; mostly tables and squares; lozenges.
Acid in large quantity, added to a strong solution of urate of ammonia . . .	Large and long tables, with very elongated lozenges.
Acid strong; amorphous urate itself used . . .	Acicular prisms most frequent.

The various forms which the substance assumes in urine may often be traced, by intermediate stages, from one into the other; but the conditions which determine the changes have not yet been satisfactorily explained. Doubtless the length of time occupied in the formation of the crystal has much influence in determining its form; for not unfrequently one crystal is observed to acquire entirely different characters if it be allowed to remain for a longer period immersed in the urine. Some of the commonest forms met with are represented in Figs. 38 and 39. The most important crystalline forms, besides the rhombic, are the rectangular quadrilateral prisms with terminal planes, and the dumb-bell crystal. All

other forms appear to be some modification of these three. The dumb-bell form of crystals is occasionally met with in deposits; but it may often be readily obtained by the addition of an acid to urine. These crystals must not be mistaken for dumb-bells of oxalate of lime, from which they may be dis-

Figs. 38 and 39.—Some of the commonest forms of uric acid crystals.

tinguished by their large size and darker colour, and by their being readily soluble in alkalies. Pure uric acid often crystallises in micaceous plates. Uric acid deposited in urine can generally be distinguished by its colour from other crystalline deposits, although two or three instances have come under my notice in which the crystals were found to be perfectly colourless. Various forms of uric acid are represented in the *Illustrations*, Plates IV, V, VI, VII. A very curious form of crystal is referred to at p. 134, and figured in Plate XIX, Figs. 3 and 4, vol. i, of the *Archives of Medicine*.

Uric acid is sometimes deposited very rapidly, when it forms a thin glistening film, in which no indication of crystalline form can be detected. A film of this kind was brought to me some time since by Dr. Chambers. After the lapse of a day or two, well marked crystals made their appearance. Some of these films are composed of layers of small crystals, closely matted together. After the lapse of a short time, the larger

crystals grow, while the smaller ones disappear; so that at length a number of large well defined crystals are produced.

Tests for Uric Acid. When we are in doubt as to the nature of a deposit suspected to consist of uric acid, we may examine it as follows. If it consist of uric acid, it will be insoluble in hot water, but soluble in alkalies.

1. A portion of the deposit is to be dissolved in a drop of potash. The alkaline solution is then to be treated with excess of acetic acid. After the lapse of a few hours, crystals of uric acid will be formed, which must be subjected to microscopic examination.

2. A sediment, suspected to be composed of uric acid or a urate, may be placed upon a glass slide, and treated with a drop of strong nitric acid. After evaporation to dryness at a gentle heat, the slide is to be exposed to the vapour of ammonia, or a drop of ammonia may be added to the dry residue. A beautiful violet colour, owing to the formation of murexide, proves the presence of uric acid or a urate.

Of the Clinical Importance of Uric Acid. This substance exists in the blood, in combination with a base, as an alkaline or earthy urate, which is comparatively soluble. The soluble urate may be decomposed; 1, when it arrives in the uriniferous tubes; 2, subsequently, when the urine reaches the bladder; or, 3, as more commonly happens, the acid may not be set free until some time after the urine has been passed.

In the first case, the acid may accumulate and block up the tubes, or perhaps form a small concretion; but, as I shall show in the next lecture, oxalate of lime very frequently forms the real nucleus of these uric acid calculi which are so common. In the second case, if a small concretion of any kind exist in the bladder, uric acid is deposited around it, and a uric acid calculus becomes rapidly formed. The deposition of uric acid after the urine has been passed is often merely accidental, and depends upon the decomposition of the urates by a process of acid fermentation, which has been fully investigated by

Scherer. The acid crystallises sometimes very soon after the urine has been voided, sometimes not for some days afterwards. I have before alluded to the importance of not regarding the *deposition* of uric acid crystals as in all cases depending upon *excess* of the acid in the urine. There may actually be less uric acid than is present in health, although it may be deposited entirely in an insoluble form.

The *occasional* occurrence of uric acid as a deposit may be regarded as unimportant, especially when it is due to a change occurring in the urine long after its secretion. In not a few instances, however, when this deposit of uric acid is observed *day after day*, it does indicate the existence of derangement of the health. I may state generally, that you are likely to meet with this deposit in cases where a liberal meat diet is indulged in by those who take very little exercise; and in the urine of people who lead very sedentary lives, it is not uncommon. In various gouty affections, it is very frequently observed. In diseases of the liver, it is especially common; and temporary congestion of that organ is very frequently associated with the presence of much uric acid in the urine. In chronic diseases of the respiratory organs, we often meet with uric acid and urates in the urine. It is common in emphysema of the lung, and in chronic bronchitis. In pneumonia and rheumatic fever, it is often found. It is seldom absent in chorea, and very often exists in various forms of skin-disease, and in cases of acute inflammation of the kidney. It is occasionally met with in diabetes. There are many cases in which the tendency to deposits of uric acid is not very easily explained. Some children are very liable to suffer from uric acid deposits, and their appearance is accompanied by frequent desire to pass urine. In such cases, it is necessary to interfere, in case a calculus should form. I have seen instances occurring in adults in which ordinary remedies appeared to exert no effect. The urine of a patient suffering from emphysema of the lung always contained a large quantity; and it appeared while she

was taking considerable doses of alkalies, and also when she was put upon mineral acids.

Occasionally we meet with patients who appear generally in good health, but who complain of getting thin, although they live well, in many instances perhaps too well, and suffer from an almost constant deposition of uric acid. It is very difficult to explain this symptom in every case in which it occurs; but I feel sure that many of these persons overtax their digestive organs, and are in the habit of eating too much. They think that the only way to gain flesh is to consume a large quantity of food; and, in consequence of too much work being thrown upon their digestive organs, assimilation is not properly carried on, and a quantity of material is formed which is unfitted for conversion into tissue, and is perhaps got rid of in the state of urea, uric acid, and urates. By cutting off a great part of the supply, you may relieve their anxiety as to the gravel, and at the same time, to their surprise, cause them to gain strength and increase in weight.

I have already alluded to the great objection of employing the term uric acid diathesis, and have referred to the general principles which should guide us in the treatment of cases in which an excess of uric acid is eliminated in the urine.

Oxalate of Lime. The next substance which is to be noticed is oxalate of lime, which was first shown to be a common urinary deposit by Dr. Golding Bird. It is seldom deposited in quantity sufficient to be recognised by the unaided eye, or to be subjected to chemical examination.

Octohedral Crystals of Oxalate of Lime. This salt crystallises in well defined octohedra, having one axis much shorter than the two others. The crystals vary much in size, and two or three forms have been described by authors. In the cases I have met with, the different appearances of the crystals were due to the position in which they were viewed, as I shall be able to prove to you very readily by this glass model. The flattened octohedron is obviously the most common appear-

ance, because the crystal lies most easily on one of its faces. If, however, it be turned with one of the long axes directed towards the observer, while the other is held upright, the short axis will necessarily be transverse, and the crystal will appear as a long and very acute octohedron (*a*, Fig. 40). If now one of the lines formed by the meeting of two opposite faces be turned towards you, there will still be the appearance of an acute octohedron; but it will be less acute than before, and no transverse line in the centre can be made out. Upon keeping the same line towards the observer, and by carefully turning the crystal, so that the eye can see two opposite faces quite parallel to each other, the curious appearance represented in the diagram will be produced. (*Illustrations*, Plate XI, Fig. 1, *a*, *b*, *c*, *d*, *e*.)

Fig. 40.—Octohedra, dumb-bell, circular and oval crystals of oxalate of lime.

Crystals in all these positions, appearing as different forms, are commonly met with in the examination of urinary deposits. In Fig. 40 are represented octohedra in various positions, dumb-bells, and circular and oval crystals of oxalate of lime, with two cells of bladder epithelium, deposited from the urine of a patient suffering from a tense state of the skin of the

wrists and arms, a condition which is sometimes termed "hide-bound."

Many observers have figured these crystals incorrectly. Dr. Golding Bird considered that they belonged to the cubic system. Dr. Prout, however, has given a figure of oxalate of lime which clearly shows that he was aware of the exact form of the crystal. Prismatic crystals of oxalate of lime occur in some plants, and they have been observed by Beneke in urine. I found that some preparations of ordinary oxalate of lime, which had been kept for some years in preservative fluid, underwent a change in form, and were at length entirely replaced by beautiful prisms. Oxalate of lime may be obtained in its usual octohedral form from its solution in hydrochloric acid; and Neubauer states that from a solution in phosphoric acid it may be obtained in a crystalline form by neutralising the acid by soda or potash.

Dr. Thudichum has carefully examined the form of crystals of oxalate of lime obtained in different ways, and he brings all the different forms he has observed under the following heads: quadratic octohedron, crossed octohedra, quadratic octohedron and prism combined; crossed prisms; triple twins, with tropia; modifications of crossed octohedra; contortions and anomalies, including dumb-bells. He also shows, contrary to previous statements, that the salt actually possesses a polarising power, as should be the case if it belongs to the quadratic system. This is, however, difficult to demonstrate, and can be "only brought out fully by reflecting a ray of the sun through the crystal", which accounts for the fact having escaped observation. I had long ago examined crystals by the polariscope which had been mounted in Canada balsam, and had noticed that they were often slightly illuminated when the field was dark. Although I had figured the form of the crystals correctly, I must confess that I was too ready to agree with the statements made by others as to the system to which this crystal belonged; nor was I sufficiently acquainted with

crystallography to discuss this question fully. In this matter Dr. Thudichum has corrected me; and, after a reexamination of the question, it is only right that I should state that the octohedra, mounted in Canada balsam, do polarise even with a good artificial light; and therefore no argument in favour of the dumb-bell crystals being composed of oxalurate, and not of oxalate of lime, can be based on the statement that the octohedra do not polarise.

Dumb-Bell Crystals of Oxalate of Lime. Oxalate of lime, however, occurs more rarely certainly, but still not uncommonly, in another very interesting form, which was first pointed out by Dr. Golding Bird. From their resemblance to dumb-bells, these bodies are known as the dumb-bell crystals of

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Fig. 41.—Dumb-bells of oxalate of lime, of very regular form, from the urine of a child two years of age suffering from jaundice.
Fig. 42.—Small collection of dumb-bells, such as often forms the nucleus of a calculus.

oxalate of lime. Dr. Golding Bird thought that they were composed of oxalurate, and not of oxalate of lime; but the following points, in addition to what has just been stated, render this very improbable.

1. Octohedra, in all the cases I have observed, were deposited from the specimen of urine in which the dumb-bells were found, and invariably precede and follow the appearance of the dumb-bell crystals.

2. Minute calculi are often composed of dumb-bells, as may be shown by microscopical examination; and these calculi

have been proved by analysis to consist of oxalate of lime. (Figs. 42, 55.)

The crystalline matter of the dumb-bell may be dissolved out by the prolonged action of acetic acid, when something very like a cell-wall remains. A certain quantity of organic matter exists in the interior of the apparent cell, and was no doubt in intimate union with the crystalline material in every part of the crystal. (*Illustrations*, Plate XI, Fig. 2, *t*, *u*, *v*, *w*.) Some persons have stated that these dumb-bell crystals were composed of uric acid—a mistake for which it is very difficult to account, since, in their optical characters and chemical properties, they widely differ. The uric acid dumb-bell is instantly dissolved by dilute potash, and, by the addition of excess of acetic acid, rhombic crystals will be thrown down; while the true dumb-bell is insoluble in a strong boiling solution of potash. Any observer, whose eye had been accustomed to the peculiar glistening appearance of the oxalate of lime dumb-bell, would not be likely to mistake it for a dumb-bell of uric acid.

Besides the dumb-bell, it is common to meet with a number of closely allied forms, among which may be mentioned circular and oval crystals. (*Illustrations*, Plate XI, Fig. 2, *a*, *b*, *c*, *d*, *e*, *f*.) In several of the cases which have fallen under my notice, the true and perfectly shaped dumb-bell was preceded by circular and oval crystals; and these also again appeared after true dumb-bells could no longer be detected in the urine. These crystals often disappear the day after multitudes have been found; and generally they are only noticed for a few consecutive days—a circumstance which may perhaps account for the comparatively few instances in which these crystals have been noticed.

Of the Formation of the Dumb-bell Crystals. It is well known that the octohedra of oxalate of lime are commonly deposited in the urine after it has left the organism; and if urine which contains very minute octohedra be allowed to stand for a few

days, these may often be observed to increase in size, until at length they become very large crystals, while at the same time a number of new ones are developed. On the other hand, dumb-bell crystals are present in the urine when passed, and they do not increase in size or number if allowed to remain in the urine. These dumb-bell crystals seem to be formed in the renal tubes. I have found them entangled in casts in the urine of a cholera patient passed after eighteen hours complete suppression during the stage of collapse. The specimen of urine in which these casts were found was very acid, of a dark colour, and specific gravity 1024. The urine contained no albumen. The following report was made at the time of examination. Deposit very slight, consisting of transparent, smooth, and hyaloid casts, for the most part homogeneous, but in a very few of them a small quantity of granular matter was observed. In others, dumb-bell, oval and globular crystals of oxalate of lime were noticed. These dumb-bell crystals were seen only in the casts, but many octohedra were observed in the surrounding fluid. (*Illustrations*, Plate XXII, Fig. 1.)

I have seen many times a number of these dumb-bells impacted in the tubes of the kidney, especially in the pyramids. Indeed, if thin sections of this portion of human kidneys be made, these dumb-bell crystals will be observed not unfrequently. Often several may be seen in the wide portion of the tube, just before it opens upon the surface of the mamilla.

It is probable that where *octohedral* crystals are met with, connected with casts, they are deposited merely upon the surface or in the substance of the cast, after the urine has been allowed to stand for some time.

Of the Conditions under which Dumb-bell Crystals occur. I have met with a great many specimens of urine containing dumb-bells, but have been unable to associate the appearance of these crystals with any particular morbid condition. It may be interesting to refer to a few of these, which occurred in the hospital some years ago. During six months, I met with ten

or eleven cases, in which these peculiar crystals were present, out of about four hundred cases in which the urinary deposit was examined; but I have not observed that the urine containing them possesses any characters by which we might be led to suspect their presence, before resorting to microscopical examination; and, from my own observations, it does not appear that the dumb-bells are connected with any peculiar form of disease, or with any particular diathesis. They occur usually mixed with the ordinary octohedra of the oxalate, but I have found them alone; frequently they are found accompanied with urate of ammonia and crystals of uric acid, and often with both. Out of ten cases in which they were present, eight were men, and the remaining two were women, above the age of 21. Of these ten cases, nine occurred between the months of September and January, and one in April; but this may be accounted for by the fact, that during the winter I have always made a much greater number of microscopical examinations than during the summer months. It may prove interesting to give a list of the cases in which these dumb-bell crystals, or crystals allied to them in form, occurred. They were present in—

One case of chorea.

Two cases of cholera.

One case of chronic rheumatism.

One case of contraction of the skin of the neck and upper extremities, the condition to which the term "hide-bound" has been applied.

One case of boils, occurring in various parts of the body.

One case of paraplegia, depending upon diseased vertebræ.

One case of attempted poisoning by taking half an ounce of oxalic acid.

One case of eczema.

One case of epilepsy.

Out of these ten cases, in which the dumb-bell forms of crystal were present, it will be observed that only two instances occurred in which they were found in the urine of patients

afflicted with a similar disorder, and it is somewhat curious that these should be cases of cholera. The other cases differ so entirely in nature from each other, that it appears difficult to suppose that this curious form of crystal is any way dependent upon the nature of the malady, but we are rather led to conclude that these crystals arise from certain conditions in the secreting action of the kidney, unconnected with any particular disease. The dumb-bell crystals often occur in the urine of persons not suffering from any special disorder at all, who consider themselves in good health; but generally there is languor and loss of appetite, with uneasiness after eating, and the individual, without being able to give an account of any particular ailment, complains of not being quite well. Dumb-bells often occur in cases where little exercise is taken, with a full diet, and too little water. The concentration of the fluids, and imperfect oxidation, are probably causes of the formation of these crystals in cases of cholera.

Sometimes several dumb-bells adhere together, forming an irregularly shaped mass, which gradually becomes smooth by the deposition of the same material in the interstices, until a small, nearly spherical or oval, mass is formed (Figs. 42, 55). In other cases, it would appear that one or two crystals grow at the expense of the rest, and a perfectly uniform oval crystal, composed of course of numerous acicular crystals, radiating from a common centre, results. Thus the dumb-bell crystal becomes the nucleus of a small calculus, and it is easy to see how this may increase in size by the deposition of new matter externally—at first, while it remains in the straight portion of the uriniferous tube, or in that system of irregularly shaped cavities at the apex of the mamilla, formed by the convergence of several of the large tubes—then in the pelvis of the kidney or ureter, and, lastly, in the bladder itself.

Chemical Composition of the Dumb-bell Crystals. The chemical composition of these crystals has long been a matter of dispute among chemists, but it may now be regarded as nearly

certain that they consist of oxalate of lime; for since it has been shown that the dumb-bell may gradually grow into a small calculus, and that the latter is composed of oxalate of lime, we are justified in inferring that the dumb-bell or *microscopic* calculus has the same chemical composition. No difference in chemical character, refractive power, or in the action of polarised light, can be detected between the minute dumb-bell or oval crystals, and the aggregations of dumb-bells which are from time to time met with forming microscopic calculi. There cannot, in fact, be the slightest doubt of their being the same substance in different stages of deposition. Nor can there be any question of the latter being, in their turn, an early condition of the small renal oxalate of lime calculi.

Deposits associated with Oxalate of Lime. Oxalate of lime is often found associated with other deposits, particularly with urate of soda, in which case the minute crystals are easily passed over amidst the amorphous deposit, unless the latter be dissolved either by the application of heat or by the addition of a little potash previous to examination. The peculiar form of crystals of earthy phosphate described at the close of the last lecture are usually found in urine from which oxalate of lime is also deposited. Sometimes the crystals are so minute that, without care, they may be readily passed over in a microscopical examination; and very frequently the only appearance observed in the microscope is the presence of clusters composed of minute cubical or square shaped crystals, which appear almost opaque. Indeed, such clusters of oxalate of lime crystals may be easily mistaken for urate of soda, from which, however, they may be readily distinguished by the fact of their not being dissolved upon warming the slide, and by their insolubility in potash and acetic acid. Crystals of this character are often found adhering closely to hairs and other substances. Deposits of oxalate of lime and uric acid are represented in the *Illustrations*, Plate XXI, Figs. 5 and 6; and of oxalate of lime and phosphate, Plate XXII, Figs. 5 and 6.

Of the Examination of Deposits of Oxalate of Lime by the Microscope, and of their Chemical Characters. The larger crystals are readily recognised by their microscopical characters; and the only crystals I have known mistaken for them are crystals of triple phosphate, as I mentioned when speaking of the phosphatic deposits. If, however, there be any difficulty, a drop of acetic acid will soon set the question of the composition of the crystal at rest.

Oxalate of lime deposits seldom sink to the bottom of the vessel in which the urine is placed, but seem to be buoyed up by the slight mucus deposit present. When, therefore, a drop of urine is taken for examination, there is no necessity for taking it from the very bottom of the vessel, the stratum of fluid slightly above this point being often found richer in crystals. Oxalate of lime seldom occurs in urine in sufficient quantity for chemical examination. If oxalate of lime be burnt in a platinum capsule, and the carbonised residue be exposed for some time to the dull red heat of a spirit-lamp or other flame, a white deposit will remain, which will be found to be insoluble in water, but it will be dissolved in acetic acid with copious effervescence, showing that, by the process of combustion, the oxalate has been converted into carbonate. If however, the carbonate has been exposed to a bright red heat, there will be danger of its partial or complete conversion into lime, in which latter case no effervescence will occur upon the addition of an acid. In the acetic acid solution, the presence of lime may be detected upon the addition of oxalate of ammonia, oxalate of lime being quite insoluble in acetic acid.

Of Oxalate of Lime in a Clinical Point of View. There is still much difference of opinion among practitioners as to the clinical importance of oxalate of lime. There can be no doubt that, in the majority of instances, the crystals form after the urine has left the bladder; and there is good reason for believing that the oxalic acid may be formed by decomposition of the urates after the urine has been passed. The experiments

of Dr. Aldridge of Dublin show that uric acid and urates are easily decomposed into oxalic acid and oxalates. Dr. Owen Rees entertains the opinion that this substance is derived from the urates; and that, when present in the urine, it indicates the existence of urates in the blood. This physician holds "that the oxalic diathesis is merely an accidental and unimportant modification of the uric". Oxalate is often deposited in the urine of gouty cases, and it is certainly very often found among urate deposits. We may consider it as proved that there are certain conditions of the system in which both oxalates and urates are formed, and that from time to time cases occur in which one class of salts predominates. In the same case, at one period we may find uric acid and urates; after a time, these mixed with oxalates; and lastly, they may give place to a deposit of oxalate alone. Wöhler and Frerichs injected uric acid into the blood of a dog, and found oxalate of lime in the urine. Oxalate of lime passes through the alimentary canal unchanged; but oxalic acid is in part excreted in the urine, while part is decomposed in the system. Bucheim and Piotrowsky have shown that small repeated doses of oxalic acid (fifteen grains every hour for six hours) are not poisonous. Not more than 12 per cent. of that taken by the mouth appears in the urine.

Oxalate of lime is, however, not always formed *after* the urine has reached the bladder. I have shown that there is very strong evidence of its deposition in the tubes of the kidney in certain cases, in the form of dumb-bell crystals; and it must therefore have been formed at the time of the separation of the urine from the blood, if it did not exist in solution in the blood itself.

It appears, then, that oxalate of lime may be excreted in the urine when oxalic acid or oxalates are taken in the food. It may be formed in the organism itself; and it may be produced by the decomposition of uric acid and urates after the urine has left the bladder.

Beneke has shown that the earthy phosphates and oxalates increase in direct proportion to each other. The nutrition of the tissues generally would be impaired under the same circumstances; and a larger amount of earthy phosphate would pass off in the urine dissolved by the oxalic acid. (*Archiv des Vereins*, Band I, Heft 3.)

After what I have said, you will not feel surprised that the presence of oxalate of lime in the urine should afford us but little help in the diagnosis of the case. It is often discovered in almost opposite conditions. Thus it is sometimes present in poor broken down subjects, and it is found in the urine of well to do country gentlemen. It will appear when we live too well and take too little exercise. It is common in chronic pulmonary affections, as bronchitis; and it is often observed in old cases of emphysema. It is common enough in dyspeptics, and is usually met with in cases of jaundice. In various forms of general debility, in cases of overfatigue, and in men who have overworked their minds, it is perhaps the commonest urinary deposit. Lastly, I have found it many times, and in very large quantity, in the urine of men who appear in all other respects in perfect health.

It is impossible for me to enter into a discussion as to the treatment required in these cases. As a general rule, it will be found that anything which improves the general health and promotes oxidation will diminish the tendency to deposit oxalate of lime. Cold bathing, exercise, attention to diet, and the mineral acids, bitter tonics, and iron, are usually prescribed with advantage. When the dumb-bells appear frequently, it is desirable to promote their expulsion from the kidney, and prevent their formation, by giving mild diuretics with plenty of fluid; or two or three glasses of Vichy water daily will wash them out of the uriniferous tubes.

Cystine occurs occasionally as a crystalline sediment in urine, and also enters into the composition of a rare form of calculus which has been termed the cystine calculus. Cystine

was formerly spoken of under the name of cystic oxide, and the same term was applied to the calculus.

Cystine forms a whitish deposit, which is found, upon microscopical examination, to consist of characteristic *six-sided plates*, which may be distinguished from uric acid crystals of

Fig. 43.—Crystals of cystine.

the same form by dissolving a portion of the deposit in ammonia. Upon the spontaneous evaporation of this ammoniacal solution, the cystine is again deposited unchanged in its hexagonal crystals; while uric acid would have been converted into urate of ammonia, which, on evaporation, would have remained as an amorphous residue. Ammonia, it appears, merely dissolves the cystine, and does not enter into combination with it. Cystine is insoluble in boiling water, in strong acetic acid, and also in very weak hydrochloric acid; but is readily dissolved by oxalic, and by the strong mineral acids. The most remarkable property of this substance is, that it contains as much as 26 per cent. of sulphur—a character in which it resembles taurine. Potash, like ammonia, readily dissolves cystine; but it is insoluble in carbonate of ammonia. The presence of sulphur in cystine may be proved by heating the substance in an alkaline solution of oxide of lead, when a black precipitate of sulphuret of lead occurs. This test cannot be regarded as diagnostic of cystine, because all animal matters containing sulphur exhibit a similar reaction. Urine containing cystine is said to smell very much like sweet briar.

Dr. Golding Bird has observed that calculi composed of this

substance undergo a change of colour by long keeping. From pale yellow or fawn coloured, they have been found to assume a greenish grey, and sometimes a fine greenish blue tint. Crystals of cystine may be obtained from a calculus composed of this substance by dissolving a portion in a solution of potash, and adding excess of acetic acid to the alkaline solution, when the cystine will be deposited in six-sided plates. Virchow and Cloëtta have proved that cystine is sometimes found in the liver; while taurine as well as cystine have been detected in the urine.

Of *the conditions of system* which give rise to the elimination of this substance by the kidneys, little is at present known. In the majority of cases in which it has been found, the general health and nutrition of the patient have been bad. Dr. Johnson found cystine once in the urine of a prisoner, and it is from time to time met with in the urine of ill-nourished persons. When examining the urine of the insane for Dr. Sutherland (*Trans. Med. Chir. Soc.*, vol. xxxviii, 1855, p. 26), I was surprised at the number of specimens which emitted large quantities of sulphuretted hydrogen after standing a few days. It is not improbable that the sulphur resulted from the decomposition of cystine or some allied substance.

The notes of the following interesting case were sent to me by Dr. Milner Barry of Tunbridge Wells, who also procured some specimens of the urine for analysis.

Case. "Mr. A., aged 23, dark complexion, well built and well nourished, of active habits, assiduously engaged in the duties of a laborious profession, suffers occasionally from sick headache, but is otherwise in the enjoyment of excellent health. The presence of cystine was ascertained microscopically at the beginnning of October 1857; but, as deposits supposed to be urates had often been previously noticed, the probability is that the cystine had been excreted in the urine for a long time. It seems now never to be absent from the urine. Debilitating agencies, and whatever promotes the metamorphosis of tissue,

intellectual exertion, active bodily exercise, mental anxiety, and smoking, appear to cause an increase in the amount of cystine. You will observe the much larger relative proportion of the ingredient in the morning urine than in that passed in the evening a few hours after a meal. There is no lumbar pain, and no irritability of the bladder." (*Archives of Medicine*, vol. i.)

The first specimen of urine was received in October 1857. It was of the natural colour, of acid reaction, and had a smell not unlike that of sweet briar. Specific gravity, 1028.

Analysis 61.

			In 100 grs. of solid matter.
	Water	937.60	
	Solid matter	62.40	
	Urea	32.80	51.28
	Uric acid	.50	.80
	Extractive matter	12.90	20.67
Fixed salts 16.00	Sulphuric acid	1.70	2.72
	Chloride of sodium	12.00	19.23
	Earthy phosphates	1.00	1.602
	Alkaline phosphates	2.50	4.00

The next specimens were received on January 28th, 1858. No. 62 was passed on the morning of the 27th, at eight o'clock (before breakfast). Its specific gravity was 1034.

Analysis 62.

			In 100 grs. of solid matter.
	Water	916.00	
	Solid matter	84.00	
	Cystine	.906	1.08
	Urea	49.00	58.33
	Extractives	16.94	19.52
Fixed salts 17.6*	Chloride of sodium	9.30	11.07
	Sulphuric acid	4.50	5.35
	Earthy phosphates	.60	.71
	Alkaline phosphates	4.20	5.00

* In these analyses the fixed salts were estimated by incineration, while the sulphuric acid, phosphoric acid, and chloride of sodium, were estimated volumetrically. The slight discrepancy in the numbers arises partly from the volatilisation of some of the saline constituents during incineration, and partly from slight errors in the analyses, unavoidable when only small quantities are operated on.

No. 63 was passed at 9 P.M. on the 26th, three hours after dinner. Specific gravity, 1027.

Analysis 63.

			In 100 grs. of solid matter.
	Water	949.30	
	Solid matter	50.70	
	Cystine	Too little to estimate	
	Urea	28.40	56.01
	Extractives	1.30	2.76
Fixed salts 19.6	Chloride of sodium	11.20	22.09
	Sulphuric acid	1.90	3.74
	Earthy phosphates	.60	1.18
	Alkaline phosphates	2.30	4.53

In these analyses, it is interesting to notice that the sulphuric acid is by no means deficient; indeed, in the second, the amount present is considerably above the average quantity met with in healthy urine. The proportion of cystine present, although occupying a considerable bulk, is really very small; so that the opinion commonly entertained with reference to cystine being a compound in which the sulphur is removed from the organism in an unoxidised state, in consequence of the oxidising processes being in a low condition, will not explain its formation in the present instance, as the analyses prove that a much larger quantity of sulphur passed off as sulphuric acid than in a state of combination in the form of cystine. It is interesting to notice the large proportion of sulphuric acid present when the cystine existed in sufficient amount to be determined quantitatively.

Carbonate of Lime is said to occur occasionally in the crystalline form in human urine; its microscopical characters are somewhat similar to those of the carbonate of lime which is met with in the urine of horses and other herbivora; but the crystalline spherules are smaller and more delicate. From the drawings given, it would seem that the slender crystals of which the globular mass is composed are not arranged so compactly together as in the case of the salt so common in horses' urine. In highly alkaline urine, in which the alkalescence is caused

by carbonate of ammonia set free by decomposition of urea, carbonate of lime occurs in small quantity, but in an amorphous form. This is the only form in which I have yet seen carbonate of lime in human urine. Carbonate of lime may be recognised by the effervescence produced upon the addition of a drop of acetic acid to the deposit suspected to contain it, care being taken that the sediment be well washed with distilled water before adding the acid, in order to remove any soluble carbonate that may be present. Urinary calculi containing carbonate of lime have been met with, but they are not common. Mr. Hitchings of Oxford has removed two or three, which are deposited in the Oxford Museum. Chalk or marble is occasionally added to urine, for the purpose of deceiving us. The presence of these substances is easily recognised by the action of acid, and by their being insoluble in water.

Silica, it is asserted, in a few instances forms a constituent of some calculi. Berzelius long ago showed its presence in minute quantity in the ash of human urine; but it has never been met with as a deposit in this secretion, unless placed there in the form of sand, for the purpose of imposing upon us. I have received the urine of a hysterical girl for examination, containing nearly a fourth of its bulk of common house-sand. In this quantity, we could hardly fail to detect its composition; but the presence of a few grains might possibly give rise to some little difficulty, when they were found in urine. Their nature, however, would be determined by treating them with boiling nitric acid, in which they are quite insoluble. Under the microscope, they appear as crystalline particles, of a very irregular form.

Blood-Corpuscles usually form a red or brownish-red granular deposit, which sinks to the bottom of the vessel. A few corpuscles are diffused through the tissue. If the urine be perfectly neutral, or slightly alkaline in its reaction, the colour of the globules will be bright red; while, in those instances in which the reaction is decidedly acid, the globules

will be found of a brown colour, imparting to the supernatant fluid a smoky hue. When the urine has a decidedly smoky appearance, it will generally follow that the blood is derived from the kidney; while, in the majority of cases in which it retains its florid colour, it comes from the bladder, prostate, or urethra. Occasionally, however, when the urine is alkaline, the blood, although it comes from the kidney, exhibits its ordinary florid red colour. If blood-globules remain long in urine, they become much altered in form, the outline appearing irregular and ragged, and the surface granular. (Fig. 44.) Not unfrequently the blood-corpuscles are swollen and very much distended. These changes, no doubt, are chiefly dependent upon physical causes.

Fig. 44.—Blood corpuscles. *a, b, c,* taken from the living body; *d, e, f,* from the urine; *d,* corpuscles smaller than natural; at *e,* their circumference serrate and ragged; and at *f,* a somewhat similar appearance is shown.

Of Blood in the Urine clinically. Blood in the urine may be derived from any part of the genito-urinary mucous membrane. In the female, it often escapes from the vessels of the uterus or vagina. It is of course always met with in the urine of the female at the catamenial periods.

Blood may come from the kidney, in consequence of recent inflammation or old standing disease leading to congestion and

subsequent rupture of the vessels of the Malpighian body, or its escape may depend upon that peculiar condition of system in which there is a tendency to capillary hæmorrhage in all parts of the body. When blood-corpuscles are found entangled in casts, we may feel certain that they come from the secreting structure of the kidney. In these cases, the urine generally exhibits the well known smoky appearance which depends upon the action of the acid of the urine upon the colouring matter of the blood. In cases in which, from various symptoms, we are led to suspect the existence of chronic kidney-disease, it is a favourable sign if the albumen is not detected after we fail, upon microscopical examination, to find blood-corpuscles. If the albumen, however, continues to be passed, we may feel certain that it was not solely derived from the serum which escaped through the ruptured capillary vessels with the corpuscles, but is to be attributed to chronic renal disease. Hæmaturia may depend upon a calculus being impacted in the kidney, or upon the existence of fungus of the kidney or bladder. Its escape may be due to disease of the bladder or prostate. In malignant disease, the patient is often terribly exhausted by the violent and frequent hæmorrhage which no remedies will restrain. Simple hæmorrhage, not dependent on organic disease, sometimes takes place from the mucous membrane of the bladder, as well as from other mucous membranes, as from that of the nose, throat, lungs, stomach, etc.

Chemical Characters of Urine containing Blood. Urine containing blood-corpuscles must also contain serum; but the quantity of this fluid is in many cases very small, although numerous blood-corpuscles are to be discovered by microscopical examination. If there be much blood, the albumen of the serum is readily detected by the ordinary reagents.

Circular Sporules closely resembling Blood-Corpuscles. Occasionally the sporules of fungi are found in urine which very closely resemble blood-corpuscles in size, and also in their

general appearance. (*Archives of Medicine*, vol. ii, p. 49.) Upon very careful examination, however, with a high power, a little point may frequently be observed just external to them; and not unfrequently two sporules may be seen united together. They vary in size more than blood-corpuscles. A short time since, I received a specimen of urine from a friend which contained numerous sporules; and the resemblance to blood-corpuscles was so great that, had I examined the specimen

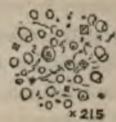

Fig. 45.—Circular sporules resembling blood corpuscles from acid urine.

carelessly, I should certainly have considered them to be of this nature. By using a power of seven hundred diameters, their characters were distinctly made out. In these cases, albumen due to the existence of kidney-disease may be found in small quantity, which would complicate the case, and increase the chance of our being led to form a wrong conclusion. When doubt exists, the deposit should be set aside for a few days, when the spores will germinate, and all question as to their nature will be removed.

Bodies rarely met with in Urinary Deposits, and Substances of a doubtful Nature.

Under this head I must include tubercle and cancer, and a few bodies of the nature of which I am not perfectly certain. Some of these substances have been carefully examined by other observers, but the results have not been sufficiently satisfactory to justify positive statements as to their nature.

Cancer-Cells. In cases of cancer of the bladder, it is not uncommon to meet with well defined cancer-cells in the urine. Some time since, Mr. Fergusson requested me to examine for

him a small portion of gelatinous-looking matter, which had been passed by a patient suffering from bladder-affection. Of the exact nature of this matter there had been some difference of opinion. Upon treating a fragment of it with a little glycerine and water, and subjecting it to examination with a power of two hundred diameters, I had no difficulty in making out loops of capillary vessels covered with a thick layer of cancer-cells. The specimen presented the usual appearances which distinguish a cancerous tumour which is rapidly growing into a hollow viscus, and was evidently one of the tongue-like or villous processes, broken off from the mass. There could, therefore, be no further doubt as to the exact nature of the case. The diagnosis was confirmed by subsequent examination of the parts.

From time to time, specimens of urine are sent for examination containing numerous well defined spindle-shaped cells, which, from their general resemblance to the cells of scirrhus, are sometimes considered to prove the existence of this terrible malady in connexion with the kidney or bladder. In several such instances, I have no doubt that the cells in question have been derived from the ureter, and their presence was quite unconnected with disease. It is very important to bear in mind that the epithelium of the ureter, and some cells derived from certain parts of the mucous membrane of the bladder, very closely resemble in form and general appearance the drawings which are given of the cells of hard cancer.

Tubercle. Tubercle is occasionally met with in urinary deposits. Dr. Thudichum (*The Pathology of the Urine*, p. 265) alludes to a remarkable and undoubted case which he saw in the Brompton Hospital. It is often very difficult to identify tubercular matter in sputum; and in many cases where the deposit escaped in the urine, the disintegration of the tubercular matter would be so great as to interfere with its detection. The characters of tubercle are represented in *The Microscope*

in its Application to Practical Medicine, 2nd ed., pages 276 and 290.)

Spherical Bodies containing Nuclei and Granular Matter. Round structures presenting these characters are not unfrequently met with in specimens of urine; but I have not been

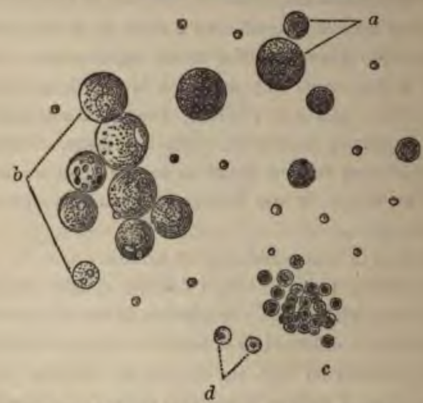

Fig. 46.—Cells from the urine of a case of acute rheumatism. *a.* In the natural state. *b.* Treated with acetic acid. *c.* Cells resembling pus. *d.* The same treated with acetic acid. The small circular bodies are blood corpuscles $\times$ 215.

able to determine with accuracy the portion of the mucous tract from which they are derived, or their pathological importance.

The cells represented in Fig. 46 were found in the urine of a patient suffering from rheumatic fever. The smaller round bodies are altered blood-corpuscles.

The large cells above referred to contained several transparent bodies within them, which became very distinct upon the addition of acetic acid (nuclei?). The central bodies did not refract like, nor did they present the circular dark and well defined outline so characteristic of, oil-globules.

In Fig. 47 are represented specimens of large cells filled

with dark granular matter, but not containing any oil-particles, from the urine of a case of chronic bronchitis. There were also a few pus-globules present in this specimen. Fig. 48 represents a curious cell found in the urine of a case of renal dropsy of seven weeks duration. Casts of medium diameter, with a few small cells containing oil, were also present in the same specimen of urine. Of the nature of these bodies I am not certain, neither have I been able to ascertain from what part of the genito-urinary mucous membrane they have been derived. Every care was taken to prevent the presence of matters of extraneous origin; but it is not impossible that some of the peculiar cells have been derived from sputum which has been altered by the action of the urine.

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Fig. 47.—Large cells filled with granular matter in the urine of a case of chronic bronchitis. × 215.

Fig. 48.—Cell found in the urine of a case of renal dropsy. × 215.

Cells presenting somewhat similar characters have come under my notice in several other cases; and from that portion of the mucous surface of the bladder known as the trigone, I have obtained cells agreeing with them in general characters. It is not unreasonable, therefore, to assume that many of these peculiar cells are modifications of bladder-epithelium.

"*Small Organic Globules*". Under this name, Dr. Golding Bird has described some little bodies smaller than the pus or mucous corpuscles, with a perfectly smooth exterior, and unaffected by acetic acid. Dr. Bird suggests that they may be

nuclei which have been set free from a cell by the bursting of the investing membrane.

Fig. 49 represents the appearance of the deposit from the urine of a patient suffering from calculus. The small round bodies represented in different parts of the figure were insoluble

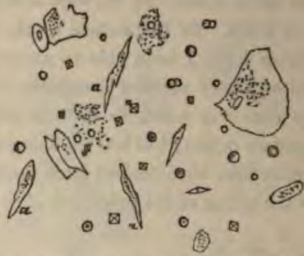

Fig. 49.—Small globules and octohedra of oxalate of lime. × 215.

in strong acetic acid, and were unaltered on the addition of ether or potash. Many of them contained a central dark spot. They were accompanied with numerous small octohedral crystals of oxalate of lime. From their highly refractive properties and chemical characters just referred to, it is probable that they were composed of oxalate of lime.

Dr. Balfour of Edinburgh (*Edinburgh Medical Journal*, vol. i, 1856, p. 617, note) has shown that altered blood-corpuscles correspond to Dr. Golding Bird's small organic globules. After the crenated margins, so often seen in blood-corpuscles in urine, have made their appearance, the globule undergoes further change, until at last it reassumes its spherical appearance, but becomes much smaller than before, and is not altered by hot or cold acetic acid. These so-called small organic globules may therefore consist of *little spherules of oxalate of lime*, *altered blood-corpuscles*, or the *sporules of fungi*. I have demonstrated the last in a great number of cases; and sometimes they form a "visible white deposit", such as Dr. Bird described. It is a pity that the name "organic globule" has

been used at all, for certainly several widely different substances answer to the descriptions given of it. The so-called "large organic globules", or "exudation-corpuscles", have been shown to consist of an aggregation of fat-globules, such as is found in cases of fatty degeneration of the kidney. I have therefore thought it better, in order to avoid confusion, not to employ the term in these lectures. (See Lecture IX; also *The Microscope in Medicine*, 2nd ed., p. 326.)

If the practitioner should meet with objects whose nature he cannot ascertain, he should at once make careful drawings, and take notes of the case in which they occurred. The importance of being familiar with the appearances of all the extraneous substances likely to be met with has been already referred to.

ENTOZOA.

Echinococci have been passed from hydatid cysts occupying the kidney, and have been found in the urine. The booklets of these creatures are very characteristic, and would be found in the urinary deposit. Mr. Simon refers to a case in which small cysts were passed entire. In these rare cases, the symptoms of a tumour connected with the kidney are present. At length the cyst bursts; the fluid with echinococci is discharged

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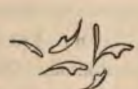

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Fig. 50.—Echinococci hominis in different positions.
Fig. 51.—Claws or hooklets of echinococci.

in the urine; and perhaps some fragments of the cyst also escape. These and the hooklets of the echinococci are perfectly characteristic, and cannot be mistaken for anything else.

(Dr. Sieveking, *Lancet*, 1853; Mr. Simon, *Lancet*, 1853; *Glasgow Medical Journal*, 1856; *Med. Times and Gazette*, 1855; also Dr. Thudichum's treatise, from which I have extracted these references. For the Characters of Echinococci, see *The Microscope in Practical Medicine*, 2nd ed., p. 361.)

Diplosoma Crenata. The most remarkable case on record in which worms were passed from the urinary bladder, is one which is reported by Dr. Arthur Farre, who has made some most careful dissections of the worm, and observations on the anatomy of the ova. (*Archives of Medicine*, vol. i, p. 290.) This is the case recorded by Mr. Lawrence in vol. ii of the *Med.-Chir. Trans.* in the year 1811. It is the only one on record. Dr. Farre describes the general characters of the worm in the article "Worms", *Library of Medicine*, vol. v, p. 241. Rudolphi, on insufficient evidence, declared that these worms were merely lymphatic concretions; and in consequence this interesting and authentic case has not yet been properly noticed by writers on parasites. From the recent reinvestigation of the whole subject, there can be no doubt that Rudolphi was wrong in his conclusions, and that these were real sterelminthous worms. In his paper above referred to, Dr. Farre at once sets all doubt on the question at rest. He now describes the minute anatomy of the worm and the characters of the ova.

The patient was a woman twenty-four years of age; and, during the course of two or three months, she passed as many as from eight hundred to a thousand worms. The worms were of two different kinds. The first form, which varied from four to six inches in length, were passed in great number. The other kind was smaller, varying from half an inch to an inch in length. These worms were passed on one occasion only; they lived in the urine for three days, and moved very briskly. They belong to the genus spiroptera, and Rudolphi gives to them the name of spiroptera hominis. The larger worms have been named by Dr. Farre, from their body being double, diplo-

soma crenata. Fig. 52 represents the general characters of the

Fig. 52.—Diplosoma crenata (Farre). One of the largest and most perfect specimens of the entozoon, half the natural size. In the centre, at the upper part of the figure, is the sharp twist or kink, where the body is most contracted. From this point each half gradually enlarges to a certain distance, but tapers again towards either extremity; the right half terminating, in this specimen, in a point, the left furnished with a lateral membranous flap. This half of the body shows the abdominal groove, and double crenate border. The right half, being spirally twisted, exhibits successive portions of the dorsal, lateral, and abdominal surfaces. This twisting is observable in many specimens. Towards the extremity of this half, numerous fibrous cross-bands are shown.

worm, one-half the natural size. The minute structure of this creature is very peculiar, and has been accurately investigated by Dr. Farre, who has illustrated his remarks with numerous drawings. There can be no doubt that, in this unique case, two new forms of intestinal worms, never seen before or since, were passed from the bladder in considerable number. For the details of the case, and for the account of the structure of the worms, I must refer you to Dr. Farre's original paper in the *Archives.*

Dactylius Aculeatus. The only case on record in which this parasite has been found in connexion with the urinary organs, is that of a girl aged five years, who was under the care of Mr. Drake. Several worms were voided; and some of them were carefully examined by Mr. Curling, whose memoir, with drawings of the worm, is published in the twenty-second volume of the *Transactions* of the Medico-Chirurgical Society. The female was four-fifths, and the male only two-fifths of an inch

in length. The tegument was armed with spines, occurring in clusters. The worms exhibited active movements; and, if left in the urine, they lived for two or three days. There were no symptoms in the case pointing to any derangement of the urinary organs. They were first noticed in the urine on May 26th, 1839, and on several occasions between this date and June 11th, after which no more worms were passed. These entozoa were, therefore, only found during a period of sixteen days, and they were not present each day.

Strongylus Gigas. This parasite appears to have been found in the human kidney on one occasion, although Küchenmeister comes to the conclusion that it has never been met with. The specimen is preserved in the College of Surgeons. It is occasionally found in the lower animals. A few years since, I obtained three beautiful specimens of the worm, two males and one female, which were found coiled up in the kidney of a large dog. The female was about fifteen inches in length, and rather less than half an inch in diameter. The skin was of a very bright blood-red colour, mottled with black. The males were about nine inches long, of a reddish brown colour, and about a quarter of an inch in diameter. The kidney was reduced to a mere fibrous cyst, rather larger than the organ on the opposite side; and the three entozoa were coiled up together, and occupied its entire cavity. The ureter was pervious all over its surface, and imbedded in the mucus of the bladder were multitudes of ova. Ova were passed in great number in the urine of this dog. The kidney and the female worm are preserved, and still in my possession.

Distoma Hæmatobium has been found in the bladder, ureters, and pelvis of kidney, as well as in the veins of the intestine, in the portal veins, small intestine, gall-bladder, etc. Griesinger states that this parasite is very abundant in Egypt. The eggs of the worm were imbedded in the mucous membrane of the bladder, which much congested and ecchymosed in these situations. The worms themselves appear to have

been found in the vessels. The eggs often form the nuclei of small deposits of uric acid. They have been found adhering to the mucous membrane of the bladder, kidneys, and ureter.

Other Worms passed from the Urinary Organs. A case is related by Raisin in which a worm three inches long was passed by a man fifty years old. Moublet alludes to the case of a boy aged 10, who voided four worms from four to five inches long, accompanied by pus. Other instances are recorded, but these do not seem to be well authenticated.

Parasites and other Animals of accidental presence in Urine. Intestinal worms are sometimes passed into the vessel containing the urine, and the patient not unfrequently affirms that they came from the bladder. Various species of acari are frequently met with in urine. It need hardly be said they are not found in the urinary organs. Insects and their larvæ are from time to time found in urine. Patients will positively assert that larvæ of the common flesh-fly have been passed through the urethra. The insect larvæ can always be at once distinguished by the presence of tracheæ in every part of their body.

Elongated Clots of Fibrine or of Blood are occasionally mistaken for intestinal worms. Microscopical examination will enable any one at once to distinguish them.

This brings us to the conclusion of the subject of urinary deposits. In my next lecture, I shall draw your attention to the most important characters of some of the principal calculi; and we shall also consider the causes which influence the deposition of these concretions from the urine, and the plans which have been proposed for their solution or removal.

LECTURE XII.

ON CALCULI. *General Consideration of the Subject. Animal Matter in Calculi. Of the Concentric Layers. Of the Classes of Urinary Calculi, and of the Chemical Examination of Calculi. Tests kept in Small Bottles with Capillary Orifices.* CLASS I. *Calculi which leave only a Trace of fixed Residue after Exposure to a red Heat. Uric Acid Calculi; Chemical Characters. Calculi composed of Urates; Chemical Characters, Uric Oxide, Xanthic Oxide, Xanthine. Cystic Oxide or Cystine. Fibrinous Calculi. Fatty Concretions.* CLASS II. *Calculi which leave a considerable Quantity of Fixed Residue after Exposure to a red Heat. Oxalate of Lime Calculi; Chemical Characters; Calculi composed of Earthy Phosphate; Chemical Characters. Carbonate of Lime Calculi. Silicic Acid Calculi. Prostatic Calculi. Summary of Chemical Characters of Calculi. Of the Origin and Formation of Urinary Calculi, and of the Nature of the Nucleus. On the relative Frequency of the Occurrence of the different Calculi. On the importance of the administration of increased quantities of fluids in certain Calculous and other affections. On the methods of dissolving Urinary Calculi. On dissolving Calculi by Electrolysis—Lithotomy and Lithotrity.*

GENTLEMEN,—We have now to consider some points in reference to urinary calculi. As there are several substances in healthy urine which possess but a slight degree of solubility, and as, in certain derangements of the physiological actions of the body, these compounds are formed in much larger proportion than in health, while other matters not present in healthy urine, and not readily soluble in water, are sometimes formed, you would readily infer that from time to time some of these

matters would be slowly deposited in the insoluble form while the urine yet remained in the bladder, or before it reached this organ. It is very interesting to consider the nature of the various conditions which are likely to lead to the formation of calculi, and it is instructive to study the condition of the system in relation to the particular form of insoluble matter that may be deposited. If we were accurately acquainted with the mode of deposition of calculous matter, it is very possible that we might lay down such rules for the guidance of patients in whom this tendency existed as would prevent the formation of the stone, or retard its increase, if already formed. You must not always look for the cause of the deposition of a calculus in the characters of the urine; for it is possible that the urine may be healthy while a stone is forming, and that the changes taking place on the surface of the stone itself may cause the precipitation of insoluble substances. Remedies which act on the kidney in many cases exert no influence upon the formation of a stone. It is very important to study the chemistry of the body carefully; and you will often find that the tendency to calculous disorder is not unfrequently explained by deranged chemical changes, which may perhaps be materially modified by attending to the action of the alimentary canal and skin, altering the mode of living, and administering the salts of the vegetable acids, alkalies, mineral acids, or mere diluents in large quantity, according to the nature of the case.

In those cases in which the deposition of the calculous matter mainly depends upon the state of the urine being unfavourable for holding certain slightly soluble matters in solution, it follows that the tendency to deposit may be averted, if the condition of the urine can be altered. It is possible that at one time an acid state of urine may favour the precipitation of uric acid; while, after a short interval, its characters may become so altered that it tends first to dissolve the uric acid, and then to precipitate phosphates, which are insoluble

in an alkali. The latter salts are soon deposited on the uric acid, and protect it from the further solvent action of the alkali.

Animal Matter in Calculi. Calculi often consist of many different constituents; but usually one predominates greatly over the rest, and the calculus is named accordingly. Even the purest calculi composed of earthy salts contain, nevertheless, a certain quantity of organic matter; and those which seem to consist of organic material only, contain a certain proportion of earthy salts. A certain amount of animal matter is deposited with the hard material, and in many cases serves to agglutinate the particles together. After the hard matter of the stone has been dissolved, this animal matter may be seen in the form of a translucent, granular, mucus-like mass. Upon microscopical examination, sometimes the remains of delicate fungi can be detected in this matrix, and very frequently dumb-bells of oxalate of lime, or fragments of them, are found. The fungi were formed during the formation of the calculus; and it is possible that the reaction developed during their growth may have exerted an influence upon the precipitation of the insoluble matter.

The hard calculous matter may consist of substances which exist in healthy urine, like phosphates and uric acid, slowly deposited from their weak solution in the secretion; or of materials which are not present in perfectly normal urine, such as oxalate of lime, cystine, etc.

Of the Concentric Layers of Calculi. The insoluble material is deposited in distinct layers, which can often be readily detached and separately examined. These layers are easily demonstrated by making a section of the calculus, which can, except in the case of the hardest and most brittle calculi, be readily effected as follows. The calculus is to be sawn through with a fine sharp saw. The cut surface is next to be ground smooth, by being rubbed down upon a smooth flat hone with water. When it is perfectly even, it may be

washed, and allowed to dry. Lastly, the cut surface is to be varnished; and now all the different layers will be seen most distinctly. If the calculus be very brittle and hard, unless it be sawn through with a diamond wheel, it is better to grind away one-half without attempting to saw through it. Small calculi are very easily ground and polished, and often furnish very instructive specimens.

The concentric layers are often of different colours, of different degrees of hardness, contain various proportions of organic base, and are of different chemical composition. Each ring forms the section of a layer, and a portion of each may be detached and chemically examined separately. Some of these layers are deposited quickly, others more slowly; and they therefore vary considerably in hardness. In examining a calculus, it will be necessary to subject a small portion of several layers separately to examination.

Seldom can any definite crystalline form be made out, except upon the surface of the concretion; and, upon examining small portions of a calculus in the microscope, nothing but a great number of crystalline fragments, exhibiting concentric layers, can usually be distinguished. Sometimes the material is deposited in little spherical masses, which become incorporated. Although distinct names are assigned to different forms of calculi, a concretion entirely composed of only one substance is seldom met with.

Of the Classes of Urinary Calculi, and of the Chemical Examination of Calculi. For convenience of description, calculi may be arranged in two classes, according to the relative proportion of the organic matter and inorganic salts present. The *combustible*, or *almost entirely combustible* calculi, are those which leave very little residue after exposure to the action of a red heat on platinum foil; while the *partially combustible* or *incombustible* calculi leave a considerable proportion of fixed residue.

I. *The first class* will include calculi composed of uric acid,

urates of ammonia, soda, lime, and magnesia, and the rare forms of uric or xanthic oxide calculi, fibrinous and blood calculi, and those consisting of cystine.

II. *The second class* will contain the oxalate of lime or mulberry calculus; the calculi composed of various phosphatic deposits; that consisting of carbonate of lime, very rare in the human subject, but not uncommon among the lower animals; and the silicic acid calculus.

The first preliminary test to which a portion of calculous matter of unknown composition is subjected, consists in exposing it to the action of a red heat. When reduced to a fine powder, a little is placed upon a piece of platinum foil, and heated in the flame of a spirit-lamp. If a carbonaceous mass remain, it is to be exposed for some time to a red heat, until it is entirely dissipated, or until nothing but a white ash remains.

If it be almost entirely dissipated, the original powder is to be tested for uric acid, urates of soda, lime, ammonia, or cystine, according to the method described for testing for these substances occurring in the form of urinary deposits.

If the powder be incombustible, or only partially combustible, it is to be tested for phosphate of lime, triple phosphate, and oxalate of lime, by the methods indicated. (See Tables.)

Tests kept in Small Bottles with Capillary Orifices. Let me direct your attention to a very convenient plan of keeping reagents, which is not only applicable to the subject now under consideration, but will be found of great advantage in all cases in which only a very small portion of matter is to be subjected to examination, particularly in ascertaining the chemical characters of substances which form the subject of microscopical inquiry—in fact, the plan of examining the chemical composition of a substance which I am about to describe may be termed not inaptly *microscopical testing*. A chemist may carry his laboratory in his pocket; and the physician may take all the apparatus necessary for the most complete qualitative

examination he is ever called upon to make, in a space much less than that now usually occupied by the urinometer, spirit-lamp, and acid-bottles.

These little test-bottles which I now show you may be kept in a case. When we proceed to test a small portion of calculous matter, it is to be powdered, and placed on a glass slide. The cap is removed from the test-bottle containing the appropriate reagent, which is then inverted, and its capillary extremity placed near to the matter or drop of solution to be tested. The warmth of the hand expands the air contained in the bottle, and a drop of the liquid is expelled.* (*How to Work with the Microscope*, *The Microscope in Practical Medicine*.)

In this way, a drop of an unknown solution can be readily subjected to the action of several tests, and indications of the presence of certain substances may be obtained as clearly as if much larger quantities were operated on. In testing for carbonates, the powder or solution may be lightly covered with a piece of thin glass, and the acid subsequently added; the slightest effervescence becomes at once clearly perceptible; and, if necessary, the specimen may be subjected to microscopical examination, and thus the smallest disengagement of air-bubbles can be detected.

Class I. *Calculi which leave only a Trace of Fixed Residue after Exposure to a Red Heat.*

Uric Acid Calculi. Nearly two-thirds of the calculi in the museums of this country consist in great part of uric acid. They vary very much in size. Sometimes small calculi are found in great number in the kidney. For the most part, the uric acid is deposited in the first instance in the kidney itself; and not unfrequently the small concretion becomes impacted

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* These test-bottles are to be obtained of Mr. Matthews, Portugal Street, Lincoln's Inn. Some are fitted up in a box, with appropriate apparatus for examining urine.

in the lower part of the uriniferous tubes or infundibula, and gives rise to great irritation, until it becomes released, and passes down the ureter into the bladder. It may now pass off by the urethra; or may remain in the bladder, when layer after layer is added, until it attains a considerable size.

Fig. 53.—Uric acid deposited upon a smaller calculus composed of oxalate of lime.

The uric acid calculus is usually of an oval form, but somewhat flattened on two of its surfaces. It is sometimes quite smooth externally, sometimes rough, or covered with a number of rounded projections. It is generally of a brownish hue, varying from a pale fawn colour to a dark brownish red. Dr. Rees met with one specimen in which the nucleus was quite white, and was composed of pure uric acid destitute of colouring matter. Its consistence is usually hard, and its texture compact. It breaks up into small angular pieces. I have examined many small uric acid calculi, and in several instances have found that the nucleus consisted of matter insoluble in potash, which polarised readily; and, in some specimens, well defined dumb-bell crystals of oxalate of lime were discovered. In some few cases, the nucleus probably consisted originally of mucus or some soft matter, which after a time had shrunk and nearly dried up, leaving a space or cavity in the centre of the calculus; but, even in these, matter insoluble in potash and acetic acid exists. Very generally, dumb-bells of oxalate of lime form the nucleus of uric acid calculi. The uric acid calculus is often coated with phosphates. The irritation of the calculus, according to Dr. G. O. Rees, excites the secretion of

an abnormal quantity of alkaline fluid from the mucous membrane of the bladder, which causes the earthy phosphates to be precipitated from their solution in the urine. If ammonia were set free by the decomposition of the urine, it is possible that a little of the uric acid calculus might even be dissolved; but this would soon be prevented by the deposition of earthy phosphate upon the surface. The phosphates are not *secreted* in increased quantity by the mucous membrane of the bladder, as was formerly believed, but are precipitated from their solution in the urine.

Chemical Characters. Insoluble in boiling water; soluble in potash. From the alkaline solution, crystals of uric acid may be obtained by adding excess of acid. The murexide test may be applied. (See Uric Acid.) When heated on platinum foil, it evolves an odour of burnt horn. Carbonate of ammonia and hydrocyanic acid are among the products of decomposition. The small amount of residue which remains after the ash has been exposed to a red heat for some time, consists principally of phosphates and carbonates of soda and lime.

Calculi composed of Urates. These calculi usually contain urates of soda, ammonia, and lime; and not unfrequently small quantities of oxalate of lime are deposited with the urates. This calculus is in great part soluble in boiling water, and gives off ammonia when heated with a strong solution of bicarbonate of potash. Dr. Prout states that it is principally met with in children, and is usually small in size, of a pale brown colour. Layers of urate are often found in uric acid calculi.

Chemical Examination. After treating the calculus with boiling water, the insoluble matter is to be separated by filtration. This may consist of oxalate of lime and phosphates. If only a little boiling water has been added, the urate will be deposited as the solution cools. The solution is to be tested as follows. Acetic acid precipitates the uric acid. Filter,

evaporate the solution to dryness, and expose the residue to a red heat. Carbonate of soda and carbonate of lime remain. The last may be obtained by solution in acetic acid and precipitation as oxalate.

Uric Oxide, Xanthic Oxide, Xanthine. These names have been given to a rare form of calculus, which has only been found in man on three occasions. It is not soluble in water; it is hard, of a yellowish brown colour, and the surface can be polished by friction. Scherer has found xanthine in the liver and spleen, in muscle, and in blood. It is closely allied to uric acid, and also to hypoxanthine, which only differs from it in containing two atoms more of oxygen.

Cystic Oxide, Cystine. This form of calculus is of a pale greenish colour; its surface is smooth, and there are no indications of concentric layers. The fracture is glistening, and the structure is semitransparent.

The chemical characters of this calculus are the same as those of cystine.

Fibrinous Calculus. This form was first noticed by Dr. Marcet, and it appears to consist entirely of an elastic organic substance closely allied to fibrine. It is said to resemble yellow wax in its appearance. It dissolved in potash, but was precipitated by excess of acid. It was insoluble in water, alcohol, and ether; but was dissolved by acetic acid, with the aid of heat. In this solution, ferrocyanide of potassium produced a precipitate. It left very little fixed residue after exposure to a red heat.

Blood-Calculi. Dr. Scott Alison furnishes the following interesting remarks with reference to a case in which he discovered some blood-calculi in the kidney. (*Archives of Medicine*, vol. i, p. 245.) In examining the body of a man named William Solly, who was admitted into the Consumption Hospital, Brompton, under the care of Dr. Cursham, on August 23rd, and who died on the 30th of the same month, the left kidney was found by Dr. Alison to be greatly atrophied and

changed in structure, while the infundibula and pelvis were stuffed with hard bodies, most of which were of a coal-black colour. "The black calculi occupied the pelvis, while the infundibula were tenanted with a few calculi of a whitish grey colour, with one exception small in size, about the magnitude of pear-seeds, and wanting the ordinary physical characters of phosphate of lime. One calculus, which occupied an infundibulum, is the size of a horse-bean, looks somewhat worn and disintegrated, and at one point resembles a piece of decayed wood. At one side it is black, from the presence of altered blood. It is very light in weight, and is composed of blood and phosphate of lime. The black calculi, which form the chief point of interest in the case, were about six in number, and ranged from the size of a coriander-seed to that of a small horse-bean. When found, these black calculi were tolerably hard; but, being friable, they partly broke asunder in handling. The fractured surface varied a little in colour, in some parts presenting a dark rusty tint." Liquor ammoniæ dissolved them; they were capable of partial combustion. The microscope revealed only amorphous particles; but Dr. Owen Rees, with the assistance of a neutral saline solution, discovered forms which he considered to be the remains of blood-corpuscles.

The kidney was remarkably altered. It was very small, but retained somewhat of the normal shape. It weighed only an ounce and a half, and was only two inches in length. Its colour was drab; its consistence was firm and fibrous. At one extremity only could any natural cortical or tubular structure be found. The organ resembled a sac with thin irregular walls. The lining membrane appeared healthy. The renal artery was small, thickened, and scarcely admitted a common probe. The ureter was small, but less out of proportion than the artery. The investing membrane could not be separated from the other parts with which it was connected.

"The atrophy of the kidney in this case was probably brought about by the production of inflammatory action, set up perhaps

by the presence of small calculi of phosphate of lime. Blood was probably effused in consequence, and, from suppression of urine, remained in the infundibula and pelvis, and failed to be washed down the ureter. This blood hardening would form the calculi which were discovered. After the abatement of the supposed inflammatory action, degenerative processes would supervene, and lead to the remarkable atrophy and change which the kidney presented. The duties of this altered kidney would be thrown upon the other; but, as the system was much wasted by disease, no increase of size would result.

"Only a very imperfect history of the patient could be obtained, he being very exhausted when he came into hospital. Since his death, inquiries have been made for information, but with little success. He was fifty-two years old, and by trade a painter. He had been ill with cough two years, and his feet and legs became œdematous only two weeks previous to his decease. No information could be obtained respecting his having suffered from calculi in the bladder, or from hæmaturia; but it is right to mention that no member of the family of the deceased could be found."

Fatty Concretions. These have been already alluded to under *Urostealith* (Lecture VIII.) Specimens of urine which contain large lumps of hard fatty matter will sometimes be brought to you for examination, and you should be aware of the fact that these are almost invariably cases in which the fat has fallen into the urine accidentally, or has been placed in it for the express purpose of imposing upon us. Quite lately I have seen two such specimens, which were said to be cases in which concrete fatty matter had been passed in the urine. In these, however, the fat was ordinary suet, as was proved by the presence of the fat-vesicle, white and yellow fibrous tissue, and fragments of vessels.

Class ii. *Calculi which Leave a Considerable Quantity of Fixed Residue after Exposure to a Red Heat.*

Oxalate of Lime Calculi. I have seen an oxalate of lime calculus not larger than the 1-500th of an inch, and have traced the formation of these stones through their several stages. I believe that the dumb-bell crystals formed in the kidney, in the first place become aggregated together (Fig. 54); crystalline matter is then deposited in the inter-

Fig. 54.—Small collection of dumb-bells, such as often forms the nucleus of a calculus.

stices, and gradually a microscopic calculus results, as represented in Fig. 55. These minute calculi remain probably for some time in the kidney, and slowly increase until they form the concretions known as the hempseed calculi. Not unfrequently a number of them are found in the kidney, and pass down the ureter one after the other at various intervals of time. Sometimes one becomes impacted, and gives rise to the most serious and distressing symptoms. Having arrived at the bladder the slow deposition of the oxalate may continue, or layers of uric acid or phosphate may be deposited, according to the state of the urine. In cases where the oxalate increases, the surface becomes tuberculated, in consequence of the irregular deposition of the salt; the colour varies from a pale brown to a dark

brown purple. They are commonly called the mulberry calculi. Such stones often attain a large size. They are very heavy

Fig. 55.—A very small oxalate of lime calculus formed from a collection of dumb-bells, parts of some of which are still seen on its external surface. *a*. A much smaller calculus, consisting of two dumb-bells.

and hard. On section, the laminæ are well seen, and you may often observe that the calculous matter has been deposited most unequally.

Occasionally the oxalate of lime is deposited almost colourless and crystalline. Dr. Prout figures one of these calculi.

Fig. 56.—A form of the mulberry calculus, composed of oxalate of lime, of a dark plum colour. Half the actual size.

I show you a beautiful specimen, which was given me by my

friend Dr. Gibb, and was obtained from the horse. You can see distinctly the large octohedral crystals all over it. These are some of the small hempseed calculi, white on the surface, and they also exhibit numerous beautiful crystals, although they are smaller than those in the last specimen.

Here is a beautiful example of another form of oxalate of lime calculus, in which the surface is of a pale brown colour,

Fig. 57.—Oxalate of lime calculus, of a brown colour. Its surface was very uneven. The figure represents the calculus of its natural size.

and the tubercles small and delicate compared with the mulberry calculus.

Oxalate of lime calculi often give rise to extreme pain when impacted in the kidney, and while passing down the ureter, or lodged in the bladder. In the kidney the pain is often of the most violent character, and frequently the patient suffers from many attacks before the stone is dislodged. Very frequently hæmorrhage occurs, and sometimes inflammation is excited, which terminates in the suppuration of the tissues contiguous to the stone.

Occasionally, however, in *post mortem* examinations, we are somewhat surprised to find these calculi in the kidney, although the patient never suffered from the slightest symptom during life. Here is a calculus the size of an almond, which was found fixed very firmly in one of the ureters of a man who died of another malady. Although its surface is rough, and it is half-an-inch in diameter, it caused scarcely any uneasiness, and we had no suspicion of its existence before the man died.

This large calculus (fig. 58) was removed from a man aged 45, by Mr. James H. Ceely, of Aylesbury. Mr. McCormick

Fig. 58.—Mulberry calculus weighing twelve drachms. Two-thirds the natural size. From a photograph.

sent me the following history of the case. It is not a little remarkable that a rough calculus like this, weighing twelve drachms, should have been present without causing great pain and uneasiness:—

"At the age of 15 years the patient (now 45) suffered from pain in the hypogastric region, extending along the urethra to the glans penis. At intervals during the succeeding twelve months the pain was very violent, and was at each attack followed by the evacuation of bloody urine. Occasionally since then he experienced pain in these situations, while taking horse exercise, or during unusual exertion, but *never to any great extent, and he was never compelled to seek advice.*

With these exceptions his general health, although delicate, had been good till last June (1858), when he had an accession of symptoms resembling those mentioned, but greatly aggravated. The urine, in addition to blood, contained 'gravel.' At this time he consulted Mr. Reynolds, of Thame, who detected a vesical calculus, and on the 20th September, Mr. J. H. Ceely performed the lateral operation and removed a rough, irregular, mulberry calculus, weighing twelve drachms.

"During the first ten days subsequent to the operation, the urine contained considerable quantities of pus and blood,

after which time all abnormal characters disappeared, and the patient was discharged from the Bucks Infirmary perfectly well on the 8th of October, and had suffered little pain or inconvenience. This patient had enjoyed excellent general health during a period of twenty-nine years, notwithstanding the presence of a calculus probably during the whole period."

A calculus of very curious shape, the nucleus of which consisted of oxalate of lime, is described by Mr. Price in the eleventh volume of the *Transactions* of the Pathological Society. Mr. Price removed fourteen calculi from the bladder of an old man by the lateral operation of lithotomy. Two of the calculi were peculiar in possessing several spine-like projections. The largest of these was about the size of a chestnut, and from its surface projected from eight to ten spines, two of which were upwards of half an inch in length. Surrounding the oxalate of lime nucleus were several layers of uric acid and urates, with some earthy phosphate. The spines were formed of the latter salts alone, and there was no projection of the oxalate of lime nucleus into them.

The cause of their peculiar shape could not be ascertained. The stone was not in any pouch in the bladder, but was free in its cavity, and the absence of any spines projecting from the nucleus militates against the idea of the peculiar form having been given to it while in the kidney. No *post mortem* was allowed. It seems possible that the formation of the spines might have depended upon the more rapid deposition of calculous matter on those parts opposite to the intervals between the smaller calculi, than over the part of the surface in immediate contact with them. Only the two largest calculi exhibited this peculiarity.

The circumstances under which oxalate of lime was deposited were referred to when we were discussing the characters of this urinary deposit, and the formation of the dumb-bell crystals has also been alluded to. With regard to this question, it is interesting to find that both Dr. Prout and Kletzinsky have

noticed deposits of oxalate of lime in patients who had had cholera, and that in two cases of this disease dumb-bells were found in the urine by myself. Dr. Prout also alludes to the frequency of cases of calculous disease in those who had suffered from cholera. The concentration of the fluids which occurs in these cases is favourable to the deposition of the least soluble substances in a solid form. The intermediate stages between dumb-bells and small calculi have been observed, as I have before mentioned.

Chemical Characters. The powdered calculus is soluble in the mineral acids, and the oxalate of lime is precipitated as a white powder by ammonia. Acetic acid will not dissolve oxalate of lime. After the powder has been exposed on platinum foil to a dull red heat for some time, a white ash consisting of carbonate of lime remains. This gives off bubbles of carbonic acid when it is treated with an acid. If the temperature be much higher than a dull red heat, a certain quantity of the carbonate of lime undergoes conversion into quick lime, which does not effervesce on the addition of an acid.

Calculi composed of Earthy Phosphate. Both phosphate of lime and ammoniaco-magnesian phosphate enter into the composition of calculi. Dr. Prout showed that the phosphates were very often deposited upon other calculi, while

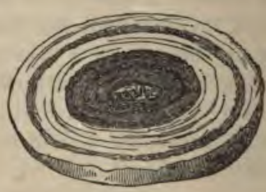

Fig. 59.—Calculus consisting principally of triple phosphate deposited round a smaller calculus composed of uric acid.

there were very few instances in which uric acid, urates, or oxalate of lime, were deposited upon the phosphate. These

two earthy salts enter into the composition of the *fusible calculus;* its degree of fusibility varying according to the proportion of triple phosphate present. The latter substance is easily fused in the blow pipe flame, while the phosphate of lime is quite infusible.

Fig. 60.—Calculus composed of phosphate of lime.

When the calculus contains but a mere trace of triple phosphate, its structure is dense and even, it is heavy, and its surface is smooth and polished; but large calculi of this kind are exceedingly rare. A small quantity of triple phosphate is almost always present in the large calculi. Portions of the laminæ of these calculi are easily broken off.

Phosphate of lime calculi are often found in the kidney. In some cases the whole of the pelvis is occupied with calculi, varying in size and shape, mixed with a considerable quantity of pulverulent matter like fine sand. Each particle of this is found, upon microscopical examination, to consist of a minute calculus, containing a certain quantity of organic matter, probably mucus and disintegrated epithelium, for its nucleus. Several of these calculi are represented in the *Illustrations*, Calculi I, Fig. 1.

Occasionally a phosphatic calculus lodged in the pelvis of the kidney gradually increases until a large calculous mass is formed by the deposition of earthy salts, layer after layer, until the whole pelvis of the kidney is occupied with it, and its prolongations extend into the infundibula and calyces.

The calculus, which consists almost entirely of triple phosphate, has a very porous structure, it is light, easily broken

down by pressure, and perfectly white. Its surface is rough, and large crystals of triple phosphate can often be discerned upon the surface with an ordinary lens.

In the deposition of phosphatic calculi, the alkali which causes the precipitation of the phosphates is secreted, according to Dr. G. O. Rees, by the mucous membrane of the bladder. The earthy salts are precipitated from the urine, not *secreted* from the mucous membrane, as was formerly supposed.

Chemical Characters. The phosphate of lime calculus is infusible. It contains, like other calculi, a little animal matter, but this is often so small that laminæ which have been exposed to a red heat retain their general characters after ignition. It is soluble in the mineral acids, and slowly in acetic acid. Phosphate of lime is precipitated in an amorphous form when the acid solution is neutralised with ammonia. When oxalate of ammonia is added to the acetic acid solution, a precipitate of oxalate of lime is formed.

The calculus composed of triple phosphate and phosphate of lime is fusible. The solution in acids, when neutralised by ammonia, gives a precipitate of ammoniaco-magnesian phosphate in stellate crystals, and a little phosphate of lime in an amorphous form. The quantity of phosphate of lime present is sometimes so small that the solution in acetic acid does not give a precipitate when oxalate of ammonia is added. Calculi composed of triple phosphate generally contain more mucus and organic matter than the other phosphatic calculi.

Carbonate of Lime Calculi, though common among herbivorous animals, have rarely been met with in man. They are friable and sometimes perfectly white. Mr. Smith has described some which are very like the mulberry calculi (*Med.-Chir. Trans.* vol. IX., p. 14). There are specimens of this form in the Oxford museum among Mr. Hitchings' collection, but unfortunately no history is attached to them. Dr. Thudichum states that he has examined prostatic concretions which consisted almost entirely of carbonate of lime. A small quantity

of carbonate of lime is usually deposited with the earthy phosphates.

This calculus effervesces freely when exposed to the action of acids previous to incineration; white oxalate of lime yields carbonate only after having been exposed to a red heat.

Silicic Acid Calculi. I have never met with calculi which contained silica; but Berzelius, Vauquelin and Fourcroy, and Mr. Venables and others, have detected it. It exists usually in very small quantity only, and in order to obtain it a considerable quantity of the calculus must be operated upon.

Prostatic Calculi. These calculi vary very much in size. The small ones are generally roundish, but often the sides are more or less flattened when many have been lying in appo-

Fig. 61.—Small prostatic calculi. Natural size.

sition. They are generally hard and white, like porcelain or alabaster. The surface is generally perfectly smooth. They consist of organic material, with phosphate of lime and a trace of carbonate; but it is seldom that triple phosphate is to be detected. The earthy matter may vary from 50 to 90 per cent.

These calculi are formed in the follicles of the prostate gland, and commence as minute very transparent concretions, which contain scarcely any hard calcareous material, and at this early period of their formation, therefore, are not entitled to the name of calculi. The microscopic concretions have been detected in the follicles during the periods of youth and early manhood by Mr. Thompson, who states that he found them in

every one of a series of fifty prostates which he subjected to examination. In old age, as is well known, they are often found of considerable size. When small, they do not give rise to any symptoms, but they may increase in size and number, and cause the greatest inconvenience and distress.

In the sections of the prostate which I show you, from a man of about forty years of age, who died from pneumonia, the various stages of growth of these concretions can be observed. The specimen has been immersed in glycerine, in order to increase its transparency, and is placed under a power of 215 diameters. Each follicle of the gland is seen to be occupied with many small roundish bodies, and a considerable number of epithelial particles. Many of the follicles are distended by a number of transparent microscopic concretions, varying from a pale yellow colour to a dark reddish brown. Some of the smallest are not more than the one two-thousandth of an inch in diameter, and yet these are seen to be composed of several concentric layers. In the centre of almost all the concretions you cannot fail to notice a quantity of minute globules, and in some you can see one or more roundish cells most distinctly. These, in fact, constitute the nucleus of the concretion. The concretions under observation consist entirely of organic matter which resists the action of moderately strong solution of potash and acetic acid. It is an albuminous material, which, in its chemical characters, agrees with the substance of which the cell wall is composed. The walls of hydatid cysts, and some of the elastic albuminoid concretions occasionally found in the peritoneal cavity, and in other situations, are composed of a substance closely allied to this. These bodies, I believe, are formed by the slow deposition of albuminous matter round a nucleus consisting of epithelial cells or *debris*. The material which is deposited in successive layers is probably the same which enters into the composition of the cells. It is sometimes colourless, but more commonly of a yellowish colour, and sometimes reddish. A small concre-

tion being once formed, new matter is poured out from the lining membrane of the follicle, deposited on it, and gradually becomes hardened by the absorption of its fluid constituents. At present there is very little earthy matter in the concretion, but gradually a change takes place, and granules of phosphate of lime are precipitated in the substance of the transparent organic matter. This change having commenced, the further separation of calcareous matter goes on. The particles already formed increase by attracting more phosphate from the surrounding fluid, which holds it in solution. As the concretion enlarges, the proportion of phosphatic salts to the organic matter becomes greater, and a *prostatic calculus* at last results. The calculus may attain a very large size, and may even extend forwards, into the urethra, and backwards, into the bladder. The characters of these concretions are well described by Mr. Thompson, whose remarks are illustrated by careful drawings (*The Enlarged Prostate.* Plates IV and V, page 265). The account above given only differs slightly from the view entertained by Mr. Thompson, who thinks that the concretions are first formed by the coalescence of the small yellow bodies or granules, which afterwards coalesce and form a small mass. Professor Quekett considers that they commence by a deposit of earthy matter in the secreting cells of the gland, while Dr. Handfield Jones believes that the concretions originate in a vesicle, which increases by endogenous growth.

You may see in various parts of the preparation concretions, the nucleus of which appears to consist of granular matter; others in which concentric layers may be traced to a central point; some which have a perfectly transparent centre; and not a few in which the nucleus is composed of small granular cells, varying in number from one to twenty, or more (*Illustrations*, Calculi Plate I, Fig. 4, *b*, *c*). For further information on this interesting subject, I must refer you to Mr. Thompson's excellent monograph on *The Enlarged Prostate*, where you will find the question of diagnosis and treatment fully discussed.

IMARY OF THE CHEMICAL CHARACTERS OF URINARY CALCULI.

1. *Calculi which leave only a slight Residue after Ignition.*

Acid. Murexide formed when a solution in nitric acid is evaporated and exposed to the vapour of ammonia. A mere trace of residue left after ignition. Ammonia not given off when treated with a solution of caustic potash.

ate of Ammonia. Reaction of mu xide. Ammonia evolved when treated with potash.

Urate of Soda. Reaction of murexide. Fuses and gives a yellow tint to the flame. Leaves a decided residue after ignition.

Urate of Lime. Reaction of murexide. Infusible. After ignition, carbonate of lime remains.

Urate of Magnesia. Reaction of murexide. Infusible. The residue after ignition dissolves, with slight effervescence, in dilute sulphuric acid. The magnesia is precipitated from this solution, in the form of triple phosphate, upon the addition of phosphate of soda and ammonia.

Xanthine does not exhibit the murexide reaction. The solution in nitric acid turns yellow on evaporation. It is not soluble in carbonate of potassa.

Cystine is soluble in caustic ammonia, and in carbonate of ammonia. It crystallises from an ammoniacal solution in six-sided plates.

Fibrine emits an odour of burnt feathers on ignition. Solution in caustic potash precipitated by acetic acid, and also by ferrocyanide of potassium after the addition of a little acetic acid.

2. *Calculi which leave a considerable Residue after Ignition.*

Triple or Ammoniaco-Magnesian Phosphate fuses in the blow-

pipe flame, and gives off an ammoniacal odour. It dissolves in acetic acid without effervescence. Ammonia gives in this solution a crystalline precipitate of triple phosphate.

Phosphate of Lime does not fuse. Soluble in hydrochloric acid. Precipitated by ammonia in amorphous granules. From a solution in acetic acid, the lime may be precipitated as oxalate when oxalate of ammonia is added.

Oxalate of Lime. Soluble in mineral acids, without effervescence. Precipitated from acid solution by ammonia. Insoluble in acetic acid. After ignition, residue effervesces freely on the addition of acids.

Carbonate of Lime. Soluble in acids, with effervescence. Lime precipitated from an acetic acid solution by oxalate of ammonia.

On the Origin and Formation of Urinary Calculi, and of the Nature of the Nucleus.

I have already had to refer briefly to this subject on two or three occasions. Whenever there is a tendency to the precipitation of any of the slightly soluble constituents of the urine in an insoluble form before the urine has left the organism, one of the conditions most essential to the formation of calculus is present. If an unusual quantity of any such substance should be formed, so that the urine contains a stronger solution of it than in health, very slight circumstances will lead to its deposition before the urine has left the bladder, and thus insoluble deposits occur. Each little mass of deposit may form a nucleus around which new matter collects; but, as a general rule, the deposit escapes with the urine. Often it would appear that on the surface, and in the interstices, of rough stones more especially, small quantities of urine are retained, and prevented from mixing with the general mass. Chemical changes soon occur, the immediate result of which is the further precipitation of insoluble material. If the urine alters in its

character, different substances may be deposited; thus, oxalate of lime may form the nucleus of the calculus; and, after this has reached a certain size, the deposition of the oxalate may give place to that of uric acid. Again, the precipitation of this substance may cease, and several successive layers of phosphate may afterwards be formed. In some calculi, these layers alternate in a very remarkable manner.

The most interesting part of the whole process is the formation of the nucleus, and it is most important that we should study this matter very carefully. If we were able to ascertain the existence of calculi at a very early period of their formation, we could in many cases, doubtless, promote their expulsion before they attained any size, and thus most distressing suffering would often be prevented, and sometimes the necessity for a severe operation removed.

Any solid matter may form the nucleus of a calculous concretion. Inspissated mucus from any part of the urinary organs—crystals which have been deposited—cells of epithelium—ova of entozoa—pieces of fibrine and small clots of blood—foreign bodies which have been introduced from without, such as peas, portions of slate pencil, or tobacco-pipe, pins and needles, and other substances which are occasionally introduced into the urethra by silly persons. A piece of a catheter and bougie have also been found in the centre of a stone.

I have lately had my attention very forcibly directed to the formation of urinary calculi, in consequence of having met with many specimens of *microscopical calculi* in urine. It is not at all uncommon to meet with microscopic uric acid calculi—aggregations consisting of uric acid crystals, which, if retained, might receive deposits of fresh material on the outside, until the small calculi, varying in size from a mustard-seed to that of a pea or larger, are formed.

Microscopical calculi of phosphate of lime are by no means uncommon, and are often found in the kidney; but until lately

I had never had an opportunity of watching the formation of calculi composed of oxalate of lime. The nucleus of these calculi does not consist of mucus or epithelium, as in the phosphatic calculus; but is of the same composition as the exterior. Fig. 54 represents a mass of dumb-bell crystals, many of which collections were passed in the urine. Although the mass is seen to consist of a number of distinct crystals these are firmly attached, so that the whole may be rolled over and over without the individual crystals being separated from each other. Such collections I have many times seen in the uriniferous tubes in kidneys obtained from *post mortem* examinations, which leaves no doubt as to the precise seat of formation of these bodies. Gradually the interstices between the individual crystals become filled up with the same material, and at the same time a few of the larger crystals increase in size at the expense of the small ones. At length a small crystalline mass of an oval form is developed, which clearly consists of a microscopic mulberry calculus, and, if retained, will gradually increase in size. (Fig. 55.) Calculi of this description are represented in the plates containing specimens of calculi in the *Illustrations*. When such calculi reach the pelvis of the kidney, a few sometimes increase gradually by the deposition of oxalate of lime upon their exterior; while, no doubt, the greater number escape with the urine, and give no trouble. Such small bodies would easily become entangled in the mucous membrane, and might remain in the pelvis of the kidney without exciting any disturbance until they had grown so large as to cause great inconvenience. If some of them passed down the ureter into the bladder, and happened to be retained for some time in this viscus, in a case where the urine contained much oxalate, they might increase in size until too large to escape by the urethra. It is, therefore, of great importance that cases in which these dumb-bell crystals are deposited should be very carefully watched. This observation is of some interest also as showing the chemical

composition of the dumb-bells, which has long been a disputed point.

As I have before stated, many small uric acid calculi, which appear to be composed entirely of this substance, will be found upon careful examination to possess a nucleus consisting of oxalate of lime, and not unfrequently by the action of liquor potassæ well defined dumb-bell crystals may be obtained. These are insoluble in potash, and also in acetic acid. I have obtained from several specimens fragments of a mass larger than that represented in Fig. 55, and no doubt formed in the same manner. From recent analyses I have made I have been led to the conclusion that the dumb-bell crystals form the nucleus, around which the uric acid is deposited, more frequently than any other substance. I have not detected oxalate of lime in the centre of the small renal calculi composed of phosphate of lime which I have subjected to examination.

On the Relative Frequency of the Occurrence of the Different Calculi.

It is often very difficult to ascertain why certain varieties of calculi should be found in greater proportion in some parts of the country than in others. The question is one of great interest in connexion with the consideration of conditions under which the formation of urinary calculi occurs.

In the collection of calculi at Guy's Hospital the proportion composed of phosphate of lime is as 1:29; at Bartholomew's as $1:32\frac{1}{4}$; while in Norwich it is as $1:132\frac{3}{5}$; and in Bristol as 1:155. Of 230 pure uric acid calculi in different hospitals in England and on the continent, as many as 164 are contained in the Norwich collection. (See the tables in the appendix to Dr. Prout's work on *Stomach and Urinary Diseases*.) In the collection of urinary calculi in the museum of Guy's Hospital, it appears, from the statement of Dr. Golding Bird, that out of 208 calculi the *nucleus* consisted of uric

acid in 127, of oxalate of lime in 47, of phosphates in 22, and of cystine in 11; or, of uric acid in 60 per cent., of oxalate of lime in 22 per cent., of phosphates in 10 per cent., and of cystine in 5 per cent. These figures are somewhat different to those given by Dr. Golding Bird, because I have thought it more correct to reckon in this calculation 142 calculi which were obtained from one individual as one.

Dr. Carter's observations on the composition of the calculi in the Grant Medical College, Bombay, prove that very few *nuclei* are composed of uric acid, while a large number consist of oxalate of lime. The following table, from Dr. Carter's paper, shows the per centage of calculi in India and in England entirely composed of uric acid, urate of ammonia, and oxalate of lime:—

	Grant Med. College. Per cent.	Coll. of Surgeons. Per cent.	Guy's Hospital. Per cent.	Norwich Hospital. Per cent.
Uric acid	3·3	32·92	15·38	24·73
Urate of ammonia	5·0	2·15	3·84	8·29
Oxalate of lime .	14·0	5·12	9·13	3·16

The following are the conclusions to which Dr. Carter has been led: "1. That, in the Bombay presidency, the proportion of calculi having oxalate of lime for their nucleus, or wholly composed of it, is about twice as great as in England, taking for comparison certain standard collections there. 2. That the proportion of calculi having uric acid, or a urate, for their nucleus or entire substance, is considerably less in India than in England; in the former, urate of ammonia calculi are somewhat more frequent than uric acid calculi; the opposite is the case in England. 3. That the number of calculi wholly composed of earthy phosphates, or having them for a nucleus, is proportionately much fewer in India than in England, the difference being chiefly owing to the rarity of the mixed phosphate in the former." (*An Account of the Calculi contained*

in the Grant Medical College Museum, with some General Remarks on Calculi in India. By H. V. Carter, M.D. Lond., Assistant Surgeon, Acting Curator of the Museum, Aug. 1859.)

It is, however, important to bear in mind that in the observations to which I have alluded, the central part of the calculus which is visible to the unaided eye is spoken of as the nucleus, while the real nucleus may be microscopic, and of a different composition to the material which immediately surrounds it. The nucleus of many calculi, which apparently consists of uric acid, is really composed of oxalate of lime, around which the uric acid has been deposited. This phosphatic calculus which I now show you (Fig. 59), seems to have a nucleus of uric acid about the size of an almond, but the latter contains in its centre a small nucleus consisting of oxalate, which can only be demonstrated by the microscope. Now the history of the formation of this is, probably, as follows: A number of dumb-bell crystals of oxalate of lime formed in the uriniferous tubes became aggregated together, and around this small mass uric acid was deposited as it lay in the tubes and pelvis of the kidney; then it passed down the ureter into the bladder, where the phosphate was deposited, and where it attained its present size. Now, the deposition of the phosphatic salts on the uric acid is not more dependent on the presence of the latter than the precipitation of the uric acid was consequent upon the presence of the oxalate. In all probability neither the phosphate nor the uric acid would have been precipitated had not the oxalate been present in the first instance. It is not too much to say that if the latter had not remained for some time in the uriniferous tubes and gradually increased in size, no calculus would have been formed in the present case; if, therefore, the collection of dumb-bell crystals had been washed out of the kidney soon after their formation by diluents, the further precipitation of calculous matter would have been entirely prevented.

It is important that we should make numerous observations

on the nuclei of various calculi, and endeavour to determine their exact nature by microscopical investigation and by the application of chemical tests. In this inquiry you will find it advantageous to take the smallest calculi and examine them as soon as possible after they have been passed. After they have become dry, it is, in most cases, quite useless to attempt investigations on the nature of the nucleus.

On the Importance of the Administration of increased Quantities of Fluids in certain Calculous and other Affections.

I have already adverted to the importance of increasing the quantity of fluid taken by persons who suffer from certain varieties of urinary deposits. This principle has been fully recognised by Prout and many practical physicians who have had experience in treating cases of this class; but the remedy, perhaps from its very simplicity, has certainly not received the attention at the hands of many practitioners that it deserves. There are conditions of the system which are very much influenced by the dilution of the blood, and many of the chemical decompositions going on are promoted by an increase in the quantity of fluid. Some changes will not take place unless the solutions of the substances be very dilute. Many comparatively insoluble matters are slowly dissolved away by the frequent renewal of the fluid in contact with them. Even silica is capable of being dissolved in water; and it is from a solution containing so slight a trace that the substance can only be detected at all by operating upon very large quantities, that the whole of the silicious matter contributing in so important a degree to give firmness to the stems of grasses is deposited. The amount of water that must pass through the tissues of the plant during its growth, and give up its silicious matter, must be enormous, since the quantity dissolved in each pint of fluid taken up by the

roots is so very small. On the same principle, by causing much liquid to traverse the tissues of a living animal, comparatively insoluble substances may be washed out. It is doubtful if that abundant deposition of urate of soda which is from time to time met with in almost all parts of the body, in certain cases, would have occurred at all, if the fluids had been constantly maintained in a proper state of dilution; and, when these crystals have been deposited, we endeavour to remove them, or prevent further deposition, by diluting the fluids of the body, and by endeavouring to increase the solubility of the urate. We are perhaps too apt, in many chronic cases, to put patients upon a plan of treatment for so short a time as a few days or weeks; and our patients are often unreasonable enough to expect that remedies will remove in a week matter which has been slowly accumulating perhaps for years. It is chronic cases of this kind which receive such real benefit from the comparatively prolonged course to which they are subjected in a German bath or hydropathic establishment; and it too often happens that, in endeavouring to perform quickly by remedies that which it is only possible to effect by giving large quantities of fluid during a considerable period of time, we disappoint ourselves and our patients; and perhaps in the end they attribute to some quack remedy or system, to which they have subsequently had recourse, a favourable result which is really due to the water they have drank and the hygienic rules to which they have been subjected, instead of to the nostrums they have swallowed.

In certain cases of gout, in chronic rheumatism, and in many cases where uric acid and urates are constantly deposited in the urine or in the tissues of the body, the most important of all things is to ensure the thorough washing out of the system. Exercise when it can be taken, hot baths, Turkish baths, etc., by promoting sweating, excite thirst; and thus more fluid is ingested, which is soon got rid of by various emunctories, carrying out with it insoluble substances, the fluid removed

being soon replaced by a fresh quantity. In the frequent repetition of these processes from time to time, a vast quantity of fluid is made to pass through the body, with the most beneficial effect.

You would be surprised how very little fluid some persons take, as a rule; and this fluid, small as it is, is often saturated with soluble substances. The fluid thus introduced is, in many persons who live well, barely sufficient to hold the various compounds in solution while undergoing chemical change. Many dislike to drink water, and not a few have a strong prejudice against it; and these are often the very individuals whom we find suffering from gout, rheumatic pains in the muscular and fibrous tissues, and various forms of urinary deposits. They will receive the greatest benefit from moderate sweating and alkalies dissolved in a large quantity of water. You will seldom find difficulty in prevailing on patients to take Seltzer, Vichy, or other alkaline waters daily, although it would be useless to recommend them to take pure water. They can take them with their wine at dinner, the last thing at night, and perhaps the first thing in the morning. People who live well, or rather too well, will soon find out that they must continue this plan, and take now and then small doses of alkalies. It is quite superfluous for me to enter into the minute details applicable in individual cases; but I cannot too strongly recommend you to study very carefully the different symptoms in cases of this class; for I feel sure that much permanent relief may be afforded such patients by explaining to them the importance of constantly attending to simple rules based on the principles to which I have adverted. Although I may have been somewhat tedious, I feel sure that you will not think that I have dwelt longer on these points than their practical importance demands; and I am convinced that we shall practise our profession with greater advantage to our patients, and advance its interests more, by studying carefully the nature of the actual processes going on in disease, and considering how these processes are

to be modified by simple means and a few remedies whose action is certain and well understood, than by hunting for new specific medicines, or combining together a great number of compounds, many of which are completely modified as soon as they enter the stomach, and are certainly destroyed long ere they reach the part of the organism where we desire that they should exert their specific influence.

On the Methods of Dissolving Urinary Calculi. I can only offer a very few remarks on this important and interesting subject. Many of the observations which I have made with reference to the prevention or removal of urinary deposits are also applicable to calculi of allied composition. When a uric acid or urate of ammonia calculus, for instance, has been deposited, it may be dissolved, or its increase may be prevented, by producing alterations in the chemical composition of the urine. This may be effected by alterations in diet, and by the administration of various remedies, especially alkalies and the salts of the vegetable acids.

It is possible also in certain instances to dissolve the stone by injecting solvents into the bladder. In many cases, however, all our attempts to remove the stone by effecting its solution will be ineffectual, and we shall have to call in the assistance of the surgeon, who may remove the stone entire by lithotomy, or may crush it with the lithotrite into several small pieces, which escape by the ordinary channel.

Mere dilution of the urine will sometimes exert a considerable influence upon a calculus; and it is possible that some calculi may have been entirely dissolved in this manner. An acid state of urine would tend gradually to dissolve a phosphatic calculus; and it is very possible that, if a feebly alkaline condition of the urine could be maintained for a considerable time, an impression might be made upon calculi composed of different forms of urates, or even upon an uric acid calculus. The irregularities often seen upon the surfaces of such calculi have been very properly termed "water-worn", and clearly

indicate that the urine has exerted, for a time at least, a solvent action. Although in certain cases it would undoubtedly be right to adopt for a time treatment of this kind, we must not look forward to the result with any great degree of confidence; at best, such changes are doubtful, tedious, and very uncertain.

Many attempts have been made to dissolve the calculus by injecting fluids, which exert a solvent power upon the stone, into the bladder. The most convenient plan is to inject the fluid through a double catheter for half an hour every two or three days, or more frequently. Dr. Willis has recommended that the fluid should be placed in a reservoir at a sufficient height above the patient, and connected with the catheter by a tube provided with a stop-cock, by which means the flow of the solvent may be carefully regulated. In carrying out this plan, it is very important that the solution should be so weak as to prevent all chance of the mucous membrane of the bladder being injured. Sir Benjamin Brodie showed that phosphatic calculi might be greatly reduced in size, or entirely dissolved, by injecting a weak solution of nitric acid (2 to 2½ minims of strong nitric acid to an ounce of distilled water). Such a solution would also act very favourably in removing the sharp edges of fragments remaining in the bladder after the operation of lithotrity.

The objection to the use of alkalies in attempting to effect the solution of uric acid or urates is, that the phosphates are precipitated from the urine, and the calculus protected from the further action of the solvent.

The most ingenious plan for dissolving calculi was that proposed some years since by Dr. Hoskins, who employed a weak solution of acetate of lead (one grain to the ounce) with a mere trace of free acetic acid. With a phosphatic stone, double decomposition occurs. Phosphate of lead, in the form of a fine granular precipitate, and an acetate of lime and magnesia, are formed. The solution, it need hardly be said,

does not produce any irritation or unfavourable action upon the bladder.

On Dissolving Calculi by Electrolysis. Attempts have been made to disintegrate and effect the solution of calculi in the living body by the aid of galvanism. MM. Prevost and Dumas (*Annales de Chèmie*, vol. xxiii, p. 202, 1823) employed electricity for the purpose of disintegrating phosphatic calculi, by the mechanical action of the gases set free in the electrolysis of water; but only a grain per hour was thus removed. The *solution* of the calculus was not attempted in those experiments. Dr. Ludwig Melicher (*Oesterreich. Medicin. Jahrbuch*, 1848, vol. i, p. 154) tried to dissolve a calculus by the aid of electricity. It is said that two experiments on the living body were successful. (Quoted by Dr. Bence Jones).

The latest, as well as the most successful, efforts have been made by Dr. Bence Jones, who employed a solution of nitrate of potash, and decomposed this by the aid of a powerful galvanic battery. The nitric acid set free at the positive electrode would decompose the uric acid exposed to its influence, and the potassa evolved at the negative electrode would dissolve it, so that an uric acid calculus placed between them would be disintegrated at both points. The battery employed was from five to twenty pairs of Grove's plates. From 2 to 9 grains of uric acid calculus were dissolved per hour at the temperature of the body. Of oxalate of lime, ½ grain to 2 grains per hour only were dissolved. The action was four times as slow as upon uric acid calculi. Of oxalate of lime and uric acid, in alternating layers, 4½ to 5 grains were dissolved per hour. Of phosphatic calculi upwards of 25 grains were dissolved per hour.

Lithotomy and Lithotrity. This is a part of the subject which I am quite incompetent to discuss, but there are one or two recent modifications in the operation to which I may be permitted to advert very briefly. The operation of lithotomy which is usually performed by most surgeons in the present

day is the lateral one. For a discussion of the various important points connected with this operation, I must refer you to Professor Fergusson's treatise on *Practical Surgery*.

Some time since, the median operation was performed with considerable success by Mr. Allarton. Its principal advantages seem to be, that the levator ani and prostatic capsule and plexus escape injury, while the course into the bladder is most direct. There is also the advantage, that the knife is not used either to notch the prostate or to open the bladder. On the other hand, there seems to be considerable chance of injuring the ejaculatory ducts; and a surgical friend tells me that there is a want of space in manipulating with the forceps, and in seizing and extracting the stone, and that there is also some risk, especially in children, of injuring the bulb of the urethra or the rectum. This operation is described in the *Lancet*, 1859, vol. i, page 122. See also Mr. Allarton's work on *Lithotomy Simplified*. London: Ash and Flint. 1854.

In connection with the subject of lithotomy, I may remark that, in a recent improvement in the manner of carrying out the lateral operation, by Mr. Wood, the injurious effects which sometimes result from the division of the prostate and levator ani with the knife are altogether avoided. Mr. Wood employs a staff composed of two blades, which can be separated from each other while the instrument is held in position. Dilatation of the urethra is readily effected by allowing the finger to slide in between the blades. In the single case in which this operation has been performed in the living subject, it certainly succeeded admirably (*Medical Times and Gazette*, Dec. 22nd 1860).

The principal advantages of this over the ordinary lateral and median operations respectively, are, that, as the knife does not enter the bladder at all, neither the prostatic veins nor the fascial capsule are injured, nor can the ejaculatory ducts be cut. The levator ani cannot be divided, and all chance of the extravasation of urine into the pelvic areolar tissue is avoided. The form of the external incision is such that more room is

given than in the ordinary operation, while injury to all important vessels and other structures is avoided. By this proceeding, the dilatation necessary for the extraction of the stone is much more easily effected than in the median operation.

Of late years lithotrity appears to have been carried out very successfully in numerous cases in which the operation of lithotomy would have been practised formerly. The number of fatal cases resulting from lithotomy is considerably greater than that obtained from an analysis of the cases of lithotrity to which I have been able to refer. Neither does it appear that stones of very large size may not be crushed with safety; and, as far as I can learn, setting aside a few exceptional cases, it would seem that lithotomy afforded but a poor chance of safety where lithotrity could not be confidently recommended. These remarks, I need hardly say, apply only to adults. In children lithotomy is so safe an operation, while the small size of the urethra and other circumstances are unfavourable to lithotrity, that it is not likely that surgeons will have recourse to any other proceeding.

The experience especially of Sir Benjamin Brodie, Mr. Charles Hawkins, and Mr. Prescott Hewett has proved that, when performed with care, lithotrity is a most successful operation. Mr. Hawkins tells me that he has operated with success even in cases of stricture and irritable bladder, and has performed lithotrity where lithotomy could not have been undertaken. (See a case reported in the *Transactions* of the Royal Medical and Chirurgical Society for 1859). On the subject of lithotrity, I must refer you to Sir B. Brodie's paper in the twentieth volume of the *Transactions* of the Royal Medical and Chirurgical Society, in the concluding paragraph of which are these words, "My own experience has certainly led me to the conclusion that lithotrity, if prudently and carefully performed, with a due attention to minute circumstances, is liable to a smaller objection than almost any other of the capital operations of surgery."

LECTURE XIII.

ON THE VOLUMETRIC PROCESS OF ANALYSIS FOR ESTIMATING SOME OF THE CONSTITUENTS OF URINE. *Apparatus required. Burettes. Pipettes. Cylindrical Glass Measure. Beakers and other Apparatus. Weights and Measures. On the Estimation of Urea and Chlorides. Determination of the Urea. Preparation of the Solution. Performance of the Analysis. Determination of the Chloride of Sodium. Preparation of the Solution. Performance of the Analysis. Estimation of Phosphoric Acid. Preparation of the Solution. Performance of the Analysis. Determination of the Sulphuric Acid. Preparation of the Solution. Performance of the Analysis. Determination of the Sugar. Performance of the Analysis. Dr. Davy's Method of Determining Urea.* SUMMARY OF THE MOST IMPORTANT CHARACTERS OF THE CONSTITUENTS OF THE URINE IN HEALTH AND DISEASE, AND OF THEIR CHEMICAL AND MICROSCOPICAL EXAMINATION. *Directions for Instituting a rough general Examination of Urine. Microscopical Examination of Urinary Deposits.*

On the Volumetric Process of Analysis.

THE ordinary methods for determining the proportion of the most important constituents in the urine possess many defects. Chemists have long found that the results are inaccurate, and not to be depended upon at all, unless great care has been taken in the process of analysis; while they are very laborious, and require an amount of chemical skill which few possess unless they have been in habit of working for some time in a laboratory. Practitioners have for years past recognised the importance in many cases of being acquainted with the amount of the urinary constituents removed from the body in

twenty-four hours, and have desired to know how these proportions are affected by certain conditions, or by the administration of remedies, or altered by disease. Till within the last few years, the greatest practical difficulties existed with reference to carrying out such researches. The physician was not chemist enough to undertake them; and the pure chemist, not having sufficient knowledge of medicine to enable him to see the use of such inquiries, was not interested in the matter. In practice, it will, I think, be found that all such investigations, if they are to be of any real use, must be carried on by a physician who at the same time is acquainted with chemistry. Within the last few years, the process of volumetric analysis has been introduced, principally by Professor Liebig, to whom we are entirely indebted for the excellent and accurate plan of estimating the urea and chloride of sodium. Physicians may now with very little practice carry on these researches; and when a sufficient number of observations have been made in various cases of disease, very important facts will, no doubt, be elicited. These processes are not free from error; but they are sufficiently accurate for all the requirements of the physician who desires to know the relative variation of the principal substances in different cases, rather than to determine the exact quantity present in a given specimen of urine. The volumetric process is at least as accurate as the old plans; and if it be carefully carried out, with attention to certain points of detail, much more so. In cases in which very accurate results are required, I must refer the reader to Neubauer and Vogel's treatise on the urine, where rules for all the corrections are given; but, for all ordinary purposes, the plan recommended below has been found in practice sufficiently exact.* The directions here given were obtained after performing the different processes several times, and were arranged by my friend and former assistant, Dr. Von Bose,

* Neubauer and Vogel is now being translated by the New Cavendish Society.

whose original paper on the subject was published in the *Archives of Medicine.*

The principle of volumetric analysis is based upon the fact that substances combine in definite and equivalent proportions. If, therefore, we accurately measure the proportion of the test required to combine with the whole of the substance present in a solution the quantity of which we wish to know, a simple calculation, according to the chemical equivalents of the two bodies, will enable us to obtain the desired result. For instance, suppose the quantity of sulphuric acid (SO^3) in a solution is to be determined. We know that to precipitate 40 parts of sulphuric acid, exactly 122 parts of crystallised chloride of barium ($Ba\,Cl + 2\,HO$) are required,—or for 1 part of sulphuric acid, 3·05 parts of chloride of barium,—or for ·01 gramme = ·154 grain of sulphuric acid, ·0305 gr. = ·747 grs. of chloride of barium. Now, if we dissolve 30·5 gr. = 471·04 grs. of chloride of barium in 1000 cubic centimeters of water = 15444 grs. or about 1¾ pint, every cub. cent. contains ·0305 gr. = ·47 grs. of chloride of barium; and if we place this solution in a tube graduated to *cubic centimeters* or *grains*, and allow it to flow gradually into a solution of sulphuric acid as long as we get a precipitate, the number of cub. cent. used indicates the quantity of *chloride of barium* employed; and from these data we at once ascertain the proportion of *sulphuric acid* contained in the solution.

Apparatus Required.

1. *Burettes or Graduated Tubes*, Fig. 62, *d*. It is convenient to be provided with one or more holding 50 cub. cents., and graduated to half cub. cents. The lower part of the tube is drawn to a small calibre; and to its extremity a small piece of glass tube, about two inches long, is connected by a piece of India-rubber tube, *f*, so arranged that it can be compressed at pleasure by a wire-spring, as represented in the figure. When

the two extremities of this spring are pressed by the finger and thumb, fluid will flow down the tube; and when the pressure is removed, the tube is rendered impervious. This little apparatus serves the part of a stop-cock, and possesses many advan-

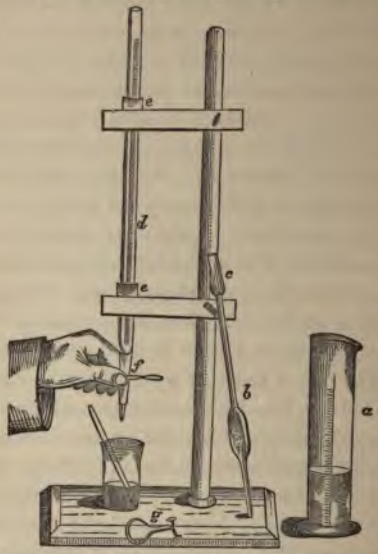

Fig. 62.—Apparatus required for the volumetric method of analysis. *a.* A glass jar capable of holding 500 C.C. graduated to five C.C. *b.* A pipette graduated to hold 20 C.C. *c.* A piece of India-rubber tube for the convenience of allowing the fluid to escape, very slowly when pressure is applied by the finger and thumb. *d.* The burette capable of holding 50 C.C. and graduated to half C.C. The numbers are not marked on the tubes in the figure. *e.* Small pieces of wide India-rubber tube to hold the burette in its place. *f.* Small piece of India-rubber tube connecting the extremity of the burette with the spout, and capable of being compressed by the spring, the form of which is represented at *g.* The mode of using the apparatus is seen in the figure.

tages over the latter. Care must be taken to keep the tube perfectly clean, and the India-rubber should be removed and well washed after every analysis.

2. *Pipettes.* The pipette is figured at *b*, Fig. 62. It is convenient to be furnished with one of 20 C. C. = 308·88 grs. capacity, one of 15 C. C. = 231·66 grs., and one of 10 C. C. = 154·44 grs.

3. *Cylindrical Glass Measure*, graduated to 500 C. C., *a*. fig. 62.

4. The little apparatus represented in Fig. 63 was constructed by me, for the purpose of filtering a little of the fluid from the deposit, in order to see if all the substance was precipitated. Filtering-paper is tied round the lower extremity, *a*. By plunging this beneath the fluid, the solution rises quite clear in the interior, and may be poured through the spout *b* into a small test-tube kept for the purpose.

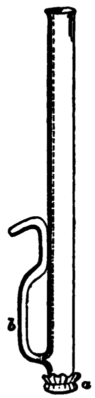

Fig. 63.—Tube for filtering small quantities of the solution in order to see if the whole of the substance in solution has been precipitated. The small tube, *b*, is curved, as shewn in the figure, in order to prevent a drop of the unfiltered fluid from running down the outside as the filtered solution is poured through the spout. Rather less than one-half the real size.

In estimating the quantity of sugar, this will be found very convenient.

5. Beakers, stirring-rods, test-paper, funnels, and porcelain

basins, with a tripod or small retort-stand, with a spirit-lamp or gas-lamp and small sand-bath, are also required.*

The test-solution is poured into the burette at the top till it is nearly full. A beaker is then placed beneath the orifice, and a certain quantity of fluid allowed to flow from the tube until the upper surface reaches zero on the scale. The line on the burette should always correspond to the lowest part of the thick line at the top of the fluid, caused by the capillary attraction of the walls of the tube. Care must be taken that the part of the tube below the India-rubber joint is also quite full of fluid.

It is desirable that the pipettes should be provided at their upper extremity with a short piece of India-rubber tube, *c*, Fig. 62, as, by properly applied pressure upon this with the finger and thumb the fluid may be allowed to escape very gradually.

Weights and Measures. In these directions, *weights* are expressed in grammes and grains, and *measures* in cubic centimeters and grains, so that the observer may adopt either as a standard of comparison. Tubes graduated to grains can easily be obtained, if required. The grammes, gr., and cubic centimeters, C.C., being always placed before the grains, grs. Thus, ·01 gr. = ·154 grs. is to be dissolved in 1 C.C. = 154 grs. of water.

Estimation of Urea and Chlorides. The determination of urea and chlorides is effected by solutions of pernitrate of mercury ($HgO.NO^5$). The principle upon which the method depends is, that *chlorine* gives a soluble, and *urea* an insoluble, compound with peroxide of mercury (HgO), while that chlorine has a greater affinity for mercury than urea has; therefore, if pernitrate of mercury ($HgO.NO^5$) be added to a solution containing chlorine and urea, the chlorine will first combine

* The apparatus referred to may be obtained of Mr. Griffin, Bunhill Row, who also supplies the test-solutions; and also of Messrs. Bullock and Reynolds, Hanover Street, Hanover Square.

with the mercury, and no precipitate of urea and mercury will take place until all the chlorine has been saturated; and if we observe how much of the solution has been used before a precipitate takes place, we can learn at once the quantity of chloride present. The volume of the solution required for completing the precipitation shows the proportion of urea, as will be explained presently. The same solution, however, is not used for both these determinations, as, for convenience in reckoning, it is better they should be of different strength. In both cases, it is necessary in the first instance to remove the phosphates from the urine. In order to effect this, a mixture of 1 volume of a cold saturated solution of nitrate of baryta ($BaO.NO^5$) and 2 volumes of saturated baryta-water ($BaO.HO$) must be prepared. This is the *baryta-solution.*

Determination of Urea ($C^2H^4N^2O^2$).

Preparation of the Solution. If pure mercury is procured, 71·48 gr.=1103·93 grs. are dissolved in pure nitric acid with the aid of the heat of a sand-bath. When fumes of nitrous acid (NO^3) cease to be evolved, and a drop of the solution gives no precipitate with chloride of sodium ($NaCl$), it may be evaporated on a water-bath in the beaker in which it has been prepared, to the consistence of a syrup. It is to be diluted to make a volume of 1000 C.C.=15444·00 grs. or about 1¾ pints; a few drops of nitric acid (NO^5) being added as often as the solution becomes turbid. In this way it will be made clear again.

If the mercury of commerce is used, a somewhat larger quantity of it is treated with nitric acid as before, but the process is stopped before it is completely dissolved: it is allowed to cool, when crystals of protonitrate of mercury ($Hg^2O.NO^5$) will form. The crystals are thrown on a filter and washed with a little nitric acid. They are to be boiled with nitric acid, till no more vapours of nitrous acid are given off, and no preci-

pitate is produced if a little is dropped into a solution of chloride of sodium. By evaporating a solution to the consistence of a syrup, pure pernitrate of mercury ($HgO.NO^5$) is obtained. This is diluted, but less water added than the solution will probably require. The proportion of mercury it contains is estimated either by sulphuretted hydrogen or by potash; and lastly it is diluted, so as to contain ·772 gr. = 11·92 grs. of peroxide of mercury (HgO) in 10 C.C. = 154·40 grs.

1 C.C. = 15·44 grs. of this solution, made according to either of the above methods, indicates 0·01 gr. = 0·154 gr. of urea.

Performance of the Analysis.—In the first place, 40 C.C. = 617·76 grs. of the urine are mixed with 20 C.C. = 308·88 grs. of the baryta solution: the precipitate is filtered and 15 C.C. = 231·66 grs. of the filtrate are placed in a small beaker. These 15 C.C. contain 10 C.C. of urine. The burette is next filled with the solution, which is added as long as the precipitate is observed to increase. The following test is then applied to ascertain if a sufficient quantity has been added. A drop of the mixture is removed with a glass rod and placed on a watch-glass. A drop of a solution of carbonate of soda ($NaO.CO^2$) is then placed near the first, and the two drops are allowed to flow together. If they give a white precipitate, the process is not yet finished; more of the mercury solution must be added, and a drop tested as before, till the two drops when they coalesce give a yellow precipitate, which shows an excess of mercury. A second experiment may be made to confirm the first; and lastly, by reading the number of C.C. required, the quantity of urea contained in the urine is immediately ascertained. Still there is a correction to be made: the first drops of the solution which produced no precipitate did not combine with, and do not therefore correspond to, any of the urea present. This volume must be deducted, or about two cubic centimeters may always be subtracted from the volume of the test-solution used.

Determination of Chloride of Sodium (Na.Cl.).

Preparation of the Solution. 17·06 gr.=263·47 grs. of pure mercury are dissolved as before described, and the syrup diluted to a volume of 1000 C.C.=15444·00 grs., or about 1¾ pints, as in the last case. Or the solution of pernitrate of mercury ($HgO.NO^5$), made from the impure mercury, which has been analysed, is diluted in such proportion, that 10 C.C. of it may contain ·184 gr.=2·84 grs. of peroxide of mercury (HgO).

1 C.C. of this solution answers to ·01 gr.=·154 gr. of chloride of sodium.

Performance of the Analysis. ·40 C.C.=617·76 grs. of urine are mixed as before with 20 C.C.=308·88 grs. of the baryta solution; 15 C.C.=231·66 grs. of the filtered mixture are placed in a beaker and rendered acid by a few drops of nitric acid. The burette is filled with the test solution, which is allowed to drop into the beaker, the mixture being continually stirred with a glass rod. As soon as the precipitate at first formed does not disappear by stirring, the operation is finished, and the volume of the solution used is read off. This shows the quantity of chloride of sodium contained in the urine.

With regard to removing the phosphates, in both cases it is to be remarked that, if 1 part of the baryta solution to 2 parts of the urine should not precipitate the whole (a point easily ascertained by adding some of the baryta solution to a few drops of the filtered mixture), more of the baryta solution must be added. This then would somewhat modify the quantity of the mixture to be taken for the test. Suppose it is desired that it should still contain 10 C.C.=154·44 grs. of urine in it. 17½ C.C.=270·27 grs. of the mixture would be required, if there were three parts of baryta solution to 4 parts of urine; 20 C.C. =308·88 grs. would be taken, if there were equal parts of baryta solution and urine. More than this will hardly ever be required.

Estimation of Phosphoric Acid.

The estimation of the phosphoric acid by this process is not so exact as those last described, and the greatest care must be taken. A solution of perchloride of iron is added, after the fluid to be tested has first been mixed with a solution of acetate of soda and free acetic acid.

If perchloride of iron be added to a solution containing phosphoric acid, a precipitate of phosphate of iron is produced; at the same time hydrochloric acid, which would redissolve the phosphate, is set free from the perchloride. In order to prevent this, acetate of soda is added in the first instance; the free hydrochloric acid decomposes the acetate of soda, and acetic acid is set free, in which the phosphate of iron is insoluble.

Preparation of the Solutions. 1. *Solution of Perchloride of Iron*—15·556 gr.—240·24 grs. of pure iron wire are dissolved in pure hydrochloric acid, to which a little nitric acid has been added. The solution is evaporated to dryness on a water bath, and the residue dissolved in water and diluted to 1000 C.C.= 15444 grs. Or a solution of perchloride of iron of moderate strength is prepared. The iron is estimated as peroxide by adding ammonia, and the solution is diluted so as to contain 1·556 gr.=24·024 grs. of iron in 100 C.C.=1544·4 grs. In preparing this solution, care must be taken to avoid an excess of hydrochloric acid. One C.C. of this solution indicates ·01 gr.=·154 grs. of phosphoric acid.

2. *Solution of Acetate of Soda and Acetic Acid.* 20 grs.= 308·88 grs. of crystallised acetate of soda are dissolved in 100 C.C.=1544·4 grs. of water, and mixed with 100 C.C.=1544·4 grs. of acetic acid.

3. *Solution of Ferrocyanide of Potassium.* 1 gr.=15·44 grs. of ferrocyanide of potassium are dissolved in 100 C.C.=1544·4 grs. of water.

Performance of the Analysis. 100 C.C.=1544·4 grs. of the urine are mixed with 10 C.C.=154·44 grs. of the solution of

acetate of soda. The whole is divided into five parts—*a*, *b*, *c*, *d*, *e*—with a pipette, each part containing 20 C·C.=308·88 grs. of urine. The burette is filled with the iron solution, and into each of the parts half a C.C. more of the solution is dropped, beginning with six half C.C., so that

a, *b*, *c*, *d*, *e*, contain
6 7 8 9 10 half CC.

of the iron solution. They are left for 5—10 minutes, then 3 C.C.=46·3 grs. of each are filtered into five test-tubes kept ready; and to the filtrates 1 C.C.=15·4 grs. of the solution of ferrocyanide of potassium is added. If in any of them the deep blue colour of Prussian blue appears, the analysis is finished, and the results may be confirmed by a second experiment. If the colour does not appear, five half C.C. more must be added to each of the parts, so that

a, *b*, *c*, *d*, *e*, now contain
11 12 13 14 15 half C.C.;

and, after standing again, the same test is applied. This process must be repeated until the deep blue colour is obtained. The confirmatory analysis is better made by taking 50 C.C. =772·2 grs. of urine in each of five beakers, mixing the fluid in each of them with 5 C.C.=77·22 grs. of the acetate solution, and adding the proportional numbers of half C.C., that are near those indicated by the first experiment. If, for instance, the colour appeared at 12 half C.C., there must be added 28, 29, 30, 31, 32 half C.C., to the different portions of the urine.

Estimation of the Earthy Phosphates (*Phosphate of Lime and Magnesia*). The quantity of phosphoric acid combined with earths (earthy phosphates) may be determined as follows:—First, in one portion of the urine the whole amount of phosphoric acid is estimated as above; in another portion, the earthy phosphates are precipitated by a little ammonia, and the phosphoric acid in combination with alkalies in the filtered fluid is volumetrically determined. The difference between

both analyses indicates the quantity of phosphoric acid combined with the earths.

If the urine to be tested is alkaline, and contains a deposit of earthy phosphates, the latter must first be dissolved in as little hydrochloric acid as will take it up.

It is important to familiarise the eye with the tint of colour obtained; and care should be taken always to obtain the same tint.

Determination of the Sulphuric Acid.

Preparation of the Solution. A quantity of crystallised chloride of barium is to be powdered, and dried between folds of blotting-paper. Of this, 30·5 gr. = 471·10 grs. are to be dissolved in 1000 C.C. = 15444·00 of distilled water.

A dilute solution of *sulphate of soda* is also required.

Performance of the Analysis. 100 C.C. = 1544·4 grs. of the urine are poured into a beaker, a little hydrochloric acid added, and the whole placed on a small sand-bath, to which heat is applied. When the solution boils, the chloride of barium test is allowed to flow in very gradually as long as the precipitate is seen distinctly to increase. The heat is removed, and the vessel allowed to stand still, so that the precipitate may subside. Another drop or two is then added, and so on, until the whole of the SO^3 is precipitated. Much time, however, is saved by using the little apparatus represented in Fig. 63. A little of the fluid is thus filtered clear, poured into a test-tube, and tested with a drop from the burette; this is afterwards returned to the beaker, and more of the test-solution added if necessary. The operation is repeated until the precipitation is complete. In order to be sure that too much of the baryta-solution has not been added, a drop of the clear fluid is added to the solution of sulphate of soda placed in a test-tube. If no precipitate occurs, more *chloride of barium* must be added; if a slight cloudiness takes place, the analysis is finished; but if

much precipitate is produced, too large a quantity of the test has been used, and the analysis must be repeated.

For instance, suppose 27 half-cubic centimeters = 208.49 grs. have been added, and there is still a slight cloudiness produced, which no longer appears after the addition of another half-cubic centimeter = 7·722 grs. of the solution, we know that between 27 and 28 half-cubic centimeters are required to precipitate the whole of the sulphuric acid present, and 100 C.C. = 1544·4 of urine contain between ·135 and .14 gr. = 2·085 and 2·162 grs. of *sulphuric acid.*

Determination of the Sugar.

This method is deduced from the reaction occurring when Trommer's test is employed for testing for grape-sugar. It is well known that grape or diabetic sugar possesses the power of reducing the oxide of copper to the state of yellowish-red suboxide.

Preparation of the Solution. An alkaline solution of sulphate of copper is prepared with the aid of *tartaric acid* and *potash.* The former prevents the precipitation of the oxide of copper by the potash. 40 gr. = 617·76 grs. of crystallised sulphate of copper are dissolved in about 160 C.C·= 2471.04 of water. Next, 160 gr. = 2471·04 grs. of neutral tartrate of potash are to be dissolved in a little water, and from 600 to 700 gr., about 9500 *grs.* of a solution of soda of 1·12 specific gravity, are to be mixed with it. The solution of the sulphate of copper is added gradually, and the whole diluted with water to a volume of 1154·4 C.C. = 17828·5 *grs.*; 10 C.C. = 154·4 *grs.* of this solution correspond to ·05 gr. = 772 *grs.* of sugar.

Performance of the Analysis. 10 C.C. = 154·4 grs. of the copper solution are diluted with 40 C.C. = 617·7 grs. of water, and placed in a porcelain dish. About 20 C.C. = 308.8 *grs.* of the urine are diluted with from ten to twenty times their bulk

of water, so as to produce, for instance, 300 C.C. = 4633·2 grs. This is to be poured into the burette, and adjusted so as to fill it to the 0° of the scale. The dish with the copper solution is arranged on a sand-bath placed on a tripod stand, at a convenient distance beneath the orifice of the burette. A spirit or gas-lamp is applied until the copper solution approaches the boiling-point, when the urine is allowed to flow in gradually, until suboxide of copper ceases to be precipitated, and the solution no longer possesses a blue colour. This is ascertained by removing the lamp and allowing the deposit to settle, when the blue tinge may be observed, if the whole has not been precipitated, by tilting the basin a little and noticing the colour of the clear fluid as it flows against the white porcelain. The little filtering apparatus will also be found of value in this operation, and its employment will save time. If the solution has still a blue tinge, more urine is to be added, and the mixture again boiled for a minute. This operation is to be repeated as long as any unreduced oxide remains in solution. When the process is finished, the proportion of sugar contained in the urine is easily calculated.

Suppose 24 C.C. = 370·6 *grs.* of the diluted urine have been required to reduce the 10 C.C. = 154·4 *grs.* of the copper solution, these 24 C.C. contain ·05 gr. = ·772 *grs.* of sugar. But since 300 C.C. of the dilute solution contain only 20 C.C. = 308·8 grs. of the urine, the 24 C.C. contain only 1·6 C.C. = 24·7 *grs.* Therefore 1·6 C.C. = 24·7 *grs.* of urine contain ·05 gr. = 0·772 *grs.* of sugar, or in 100 C.C. = 1544·4 grs. of urine, 3·12 gr. = 48·18 *grs.* of sugar are present.

The volumetric process of analysis of the urinary constituents is described at greater length in Neubauer and Vogel's *Analyse des Harns*, now being translated for the Sydenham Society; and in Dr. Thudichum's *Treatise on the Pathology of the Urine.*

Davy's Mode of determining Urea. A long stout glass tube, capable of holding two and a half cubic inches, is closed at one end, and ground perfectly smooth at the open extremity, and graduated to tenths and hundredths of a cubic inch. It is to be filled more than a third full of mercury, and afterwards a measured quantity (from a quarter of a drachm to a drachm) of the urine poured in. Next the tube is exactly filled with a solution of chlorinated soda (hypochlorite of soda, sodæ chlorinatæ liquor, of the Dublin *Pharmacopœia*). Care must be taken to avoid adding too much of the solution, which must be poured in quickly. The orifice of the tube is instantly covered with the thumb; inverted once or twice, to mix the urine and hypochlorite; and placed beneath a saturated solution of salt and water contained in a cup. The mercury flows out, and the solution of salt takes its place; but, being more dense than the mixture of urine and hypochlorite, the latter always remains in the upper part of the tube. The urine is soon decomposed, bubbles of nitrogen escape, and collect in the upper part of the tube. When decomposition is complete, which is known by no more bubbles of gas being evolved, the volume collected is read off, and corrected for temperature and pressure.

One-fifth of a grain of urea should furnish by calculation ·3098 parts of a cubic inch of nitrogen at 60° F. and 30' Bar. In one experiment, Dr. Davy obtained from the same quantity ·3001; in another, ·3069.

Amount of Urea in an Ounce of Urine, as estimated by Dr. Davy, according to Liebig's Method and his own.

	Liebig's.	Dr. Davy's.
First experiment .	3·680	3·712
Second experiment .	5·328	5·472
Third experiment .	4·976	4·976

(*Dublin Hospital Gazette*, 1855, vol. i, p. 134; Braithwaite's *Retrospect*, 1854, vol. xxx, p. 109.)

Dr. Handfield Jones has found that the results obtained by this plan were not so trustworthy as could be wished, and suggests the following modification. (*Archives of Medicine*, vol. i, p. 144.)

"Lately I have used a bottle, of about six ounces capacity, with a curved tube of supply, and another to conduct away the gas into a graduated jar (Fig. 64). I put into the bottle two

Fig. 64.—*a.* Supply tube. *b.* Out leading tube. *c.* Fluid remaining in curve of supply tube. *d.* Mixture in bottle. *e.* Receiver to hold and measure the gas generated. After the urine is poured in, the supply tube is washed out with a little water. Of course, at any time, more solution of chlorinated soda (measured quantity) can be added through the supply-tube.

drachms of urine or more, adjust the outleading tube to the jar, and pour in, with a pipette, a known bulk of solution of chloride of soda.* This drives over, of course, a corresponding amount of air, and the gas generated, a further amount, so that in the jar I have an amount which—the volume of decom-

* The solution of chloride of soda used by Dr. Davy is the sol. sod. chlor. of the Dublin *Pharmacopœia*. I find that it is not every specimen that serves the purpose well; what I have used lately has been made for me by Mr. Button, Holborn Bars. A fresh solution (filtered) of chloride of lime acts very energetically and quickly, much more so than the sol. sod. chlor., but some carbonic acid is generated and passes over, which complicates the process.

posing fluid = the gas generated. I have ascertained by trial that no alteration of volume takes place when air and nitrogen are mixed. The fluid remaining in the curved supply-tube bars all escape of gas, and it is perfectly easy to empty the bottle afterwards by simply inverting it, when the contents pour out of the gas escape-tube. By shaking the bottle frequently, I can get an experiment finished in about an hour."

"In six trials (some of them being made with a straight tube of supply going to the bottom of the jar, instead of a curved one), I obtained the following results:—

		Observed.		Calculated.	
(a) 2 grains of urea	gave	3·305 C. in.	instead of	3·098 C. in.	or ·207 +
(b) 2 „	„	3·0979	„ „	3·098	or ·0001—
(c) 1·5 „	„	2·3107	„ „	2·323	or ·0123—
(d) 1·3 „	„	2·1313	„ „	2·0137	or ·1276+
(e) 2·5 „	„	3·8498	„ „	3·8725	or ·0227—
(f) 2 „	„	3·0256	„ „	3·098	or ·0724—

"These are not exact enough to satisfy me, but I do not see any source of fallacy in the mode; and, if in more skilful hands it should prove trustworthy, I think it would have much to recommend it, on the score of facility in previous preparation. The figures have been corrected for temperature and pressure."

In some comparative experiments on Liebig's and Davy's methods, Dr. Handfield Jones obtained the following results:—

Urine specific gravity 1024, full coloured—

By Liebig, gave 15·920 grains of urea per ℥i.

By Davy, „ 16·640 „ „

Urine specific gravity 1007, pale, clear—

By Liebig, ℥i gave 5·250 grains.

By Davy, ℥i „ 2·636 „

Urine specific gravity 1029, paleish, lateritious—

By Liebig, ℥i gave 16·125 grains.

By Davy, ℥i „ 17·224 „

Urine specific gravity 1018, albumen separated—

By Liebig, ℥i gave 10·500 grains.

By Davy, ℥i „ 9·760 „

Dr. Von Bose has also estimated the proportion of urea in the same specimen of urine, by the two methods. Ten cubic centimetres of six different specimens of urine gave the following results :—

		Liebig's method.		Davy's original method.
1	....	·365 gr.	....	·310 gr.
2	....	·335 „	....	·260 „
3	....	·370 „	....	·295 „
4	....	·295 „	....	·269 „
5	....	·247 „	....	·231 „
6	....	·220 „	....	·253 „

BRIEF SUMMARY OF THE PRINCIPAL CONSTITUENTS OF URINE, AND THEIR MICROSCOPICAL AND CHEMICAL CHARACTERS.

Healthy Urine. Quantity. A healthy man usually passes from 40 to 60 oz. (17500 to 26250 grains) during twenty-four hours.

Quantity of Water. Average, about 20000 grs. in 24 h., or 940 grs. per 1000 grs. of urine. Varies much even in health, and at different periods of the day.

Quantity of Solid Matter varies inversely as the water—600 to 1200 grains excreted in twenty-four hours.

Specific Gravity of the urine in health varies from 1015 to 1025; depends not only upon the quantity of solid matter in the urine, but also upon the specific gravity of the constituents. (P. 8.)

Reaction. Acid. Varies at different periods of the day. (P. 13.)

On the quantities of the various constituents in the urine in health, see Lectures I, II, III, and the tables on pp. 70, 71.

Examination of Urine. When endeavouring to ascertain if there be any abnormal condition of the urine, note its *reaction*, *the quantity* passed in twenty-four hours, its *specific gravity*, and the *amount of solid matter.* Also apply certain chemical tests, and resort to microscopical examination, if there be any deposit. (Lecture I.)

Chemical Analysis alone will show the presence of urea, uric acid, extractive matters, salts, sugar, albumen, bile; and is employed for ascertaining the composition of certain deposits. (Lectures IV and V.)

The Microscope discovers various substances which are either not recognised at all, or are with great difficulty proved to be present by other means. (Lecture VII.)

CHEMICAL EXAMINATION OF URINE.

1. *Chemical Examination with reference to Detecting the Nature of the Deposit.*

a. Light and Flocculent Deposits (Lecture IX). Deposits of this class are generally too light, and the quantity is too small, for the application of chemical tests. See *microscopical examination* of deposits below.

b. Dense and Opaque Deposits (Lecture X), usually present in considerable quantity, are of three kinds, which much resemble each other in appearance.

1. *Urate of Soda* (p. 274). Lateritious, nut-brown sediment. Varies much in colour. Urine acid.

Tests. Soluble by heat, in potash, ammonia, water. Decomposed by acid; uric acid set free.

2. *Phosphates* (p. 283). Urine usually alkaline or neutral. When triple phosphate alone is present, the urine is sometimes feebly acid.

Tests. Insoluble by heat or in alkalies; soluble in acids, and afterwards precipitated by ammonia.

3. *Pus* (p. 278). Diffused through the urine, rendering it turbid, or forming a bulky creamy deposit, with clear or turbid supernatant fluid.

Tests. Rendered glairy by potash. Albumen in urine precipitated by heat and by nitric acid. *Caution.* Albumen *may* be independent of the pus.

c. Crystalline or Granular Deposits are usually in small quantity, forming a sediment which may either be coloured or transparent and colourless. (Lecture XI.)

1. *Uric Acid* (p. 291). Colour characteristic, usually of a dark mahogany brown, sometimes paler, very seldom quite colourless. Large separate clusters of crystals. It rarely forms a granular deposit.

Tests (p. 295). Soluble in potash, nitric acid. After evaporation with nitric acid, ammonia gives the dark violet colour of murexide or purpurate of ammonia. Often mixed with blood, smoky urine. Albumen detected in the fluid.

2. *Blood-corpuscles* (p. 313). See microscopical examination.

3. *Oxalate of Lime* (p. 297.) Seldom in sufficient quantity to form a deposit visible to the unaided eye.

Tests (p. 306). Insoluble in water, potash, and acetic acid, even when boiled; soluble in mineral acids; and again thrown down amorphous, but unchanged in composition, by ammonia. By incineration, an odour like that of burnt feathers is evolved. Black ash becomes white by decarbonisation; this ash is soluble in acetic acid, with copious effervescence. Oxalate of ammonia added to acetic acid solution precipitates oxalate of lime.

4. *Silica* (p. 313) is said to have been found in very minute quantities in urine; rarely met with as a deposit, except in the form of grains of sand in the urine of hysterical patients and impostors. Easily known by its great density, general appearance, and insolubility in strong mineral acids.

2. *Chemical Examination with reference to the Discovery of an Abnormal Condition of the Soluble Constituents of the Urine, or of the Existence of Substances of a Soluble Form not met with in Health.* (Lecture v.)

1. *Albumen* (p. 131). Urine pale; often of very low specific gravity, 1005 to 1012 or 1014. Heat or nitric acid, if urine be acid; nitric acid, if the urine be alkaline. Reason: solubility of albumen in alkalies. *Fallacies.* A *trace of nitric acid* prevents the precipitation of albumen by heat (p. 134). Precipitation of phosphates by simply boiling the urine. Precipitation of

minute crystals of uric acid upon the addition of dilute nitric acid to some specimens of urine: hence necessity for employing both tests (p. 134).

2. *Excess of Urea* (p. 89). Urine frequently high coloured; specific gravity, 1030 to 1040. Upon the addition of an equal volume of strong nitric acid, crystals occur within half an hour, if there be much excess. Oxalic acid is often employed when the urea is to be determined quantitatively.

3. *Sugar* (p. 148). Urine pale, of high specific gravity, from 1030 to 1050. Trommer's test (p. 151). Potash tests (p. 151). Fermentation test (p. 160). Tartrate of copper (p. 152).

4. *Sulphates* (pp. 56, 113). Nitrate of barytes or chloride of barium, after the addition of a few drops of nitric acid.

5. *Chloride of Sodium* (pp. 59, 108). Nitrate of silver, after the addition of a few drops of nitric acid.

6. *Bile* (p. 144). Urine of a dark yellow colour. Nitric acid; play of colours. Pettenkofer's test.

DIRECTIONS FOR INSTITUTING A ROUGH GENERAL EXAMINATION OF A SPECIMEN OF URINE.

The most necessary tests may be arranged under six heads; and, by having recourse to one or more of these, we are enabled to determine roughly the most common morbid states of the urine.

1. *Reaction* (pp. 12, 82, 83).

2. *Specific Gravity* (pp. 8, 10, 81). When very high, we may suspect an increased quantity of urea (excess); the presence of sugar. Apply tests previously mentioned. Hysterical urine, and urine of cases where much water has been taken, is of very low specific gravity.

3. *Heat.* Urate of soda, distinguished from pus or phosphate (p. 275). Albumen. Precipitation of phosphate, etc. (p. 134).

4. *Nitric Acid* dissolves phosphates (p. 134); decomposes urate of soda (if strong, rapidly); precipitates albumen in urine, even when in very small quantity and due to the presence of pus. Used also to test the presence of uric acid. Excess of urea. Bile (p. 144).

5. *Potash.* Urates, distinguished from pus or phosphate (p. 274). Uric acid, from blood. Sugar indicated by a brown colour, after prolonged boiling.

6. *Nitrate of Silver* (p. 59). Precipitate of chloride of silver, insoluble in nitric acid. In certain cases, the urine does not contain a trace of chloride of sodium (p. 108).

MICROSCOPICAL EXAMINATION OF URINARY DEPOSITS. (Lect. VII.)

Great caution required in every step (p. 212). A large quantity of urine (at least four ounces) should be allowed to subside in a *conical glass* (Figs. 87, 90) for some (two or three) hours, or the greater portion of the urine may be poured off from the deposit, which may then be submitted to examination. In the last case, small bottles only need be taken to collect specimens; but, of course, no idea can be formed as to the relative amount of deposit present (p. 212). *Pipettes* (Fig. 89). *Examination in cells or cages* (Figs. 85, 86).

When the insoluble matter has subsided, the deposit may assume one of three characters (Lecture VII).

1. It may occupy a large bulk, and present a flocculent appearance; or

2. It may form a dense, opaque, and abundant or scanty stratûm; or

3. The deposit may be small in quantity, crystalline, consisting of sparkling coloûrless points, or of more or less coloured granules.

All these characters may coexist in one deposit, in which case we observe three distinct strata, each of which must be *separately* submitted to microscopical examination. In many cases, there are two distinct strata.

1. *Substances floating on the Surface of the Urine, or diffused through it, but not forming a visible Deposit.* (Lecture VIII).

a. Opalescence produced by urates (p. 233).

b. Opalescence produced by vibriones (p. 233).

c. Milk in urine (p. 234).

d. Chylous urine (p. 234).

2. *Deposit light and flocculent, occupying a considerable Bulk.* (Lecture IX.)

Always take specimens from the bottom of the glass for examination, as well as from the bulk of the deposit.

a. Simple mucus-corpuscles (p. 253), or with bladder or renal epithelium (p. 259). Cells sometimes tinged with yellow bile.

b. Simple mucus, or epithelium with numerous small crystals of oxalate of lime entangled in it (p. 597).

c. *Casts.* Various forms of casts (p. 263). *α.* Casts of medium diameter. *β.* Casts of considerable diameter. *γ.* Casts of small diameter.

d. Spermatozoa (p. 260). Vibriones (p. 256). Torulæ (p. 257). Sarcinæ (p. 258).

e. Matters of extraneous origin (p. 225). Bed-flock: hair: feathers: dust. Distinction from casts, etc. (p. 229).

3. *Deposit dense, opaque, and abundant.* (Lecture X.)

a. Urates. Amorphous deposit.

b. Pus (p. 278). Characters. Potash. Acetic acid.

c. Phosphates (p. 283). Phosphate of lime (amorphous) (p. 284). Triple or ammoniaco-magnesian phosphate (crystalline) (p. 283). Mixed with carbonate or oxalates.

d. Matters of extraneous origin (p. 225). Sand. Starch (p. 229): potato: rice: bread-crumbs: arrowroot.

4. *Granular or crystalline Deposits, small in Quantity, sinking to the Bottom, or adhering to the Sides of the Vessel.* (Lecture XI.).

a. Uric acid (p. 293). Forms of. Amorphous. Varies much in colour. Polarisation.

b. Oxalate of lime (p. 297). Forms of. Dumb-bells. Distinction of oxalate of lime from triple phosphate.

c. Phosphate of lime (p. 284). Triple phosphate, radiating crystals (p. 283).

d. Blood-globules (p. 313).

e. Cystine (p. 308). Carbonate of lime (p. 312).

f. Matters of extraneous origin (p. 225).

APPARATUS AND TESTS REQUIRED FOR THE CLINICAL EXAMINATION OF URINE.

SEVERAL of the simplest and most necessary pieces of apparatus will be enumerated under this head, and illustrations of several are subjoined in the plates which follow.

1. *Clinical Pocket Microscope*, Plate I, Fig. 65. This is a very simple and inexpensive instrument, which I have lately arranged for the microscopic examination of urinary deposits and other substances. When closed, it is only six inches in length; but, when arranged for examination, the tube is drawn out as long as that in the ordinary microscope. Any powers can be adapted to it; and direct light, or light reflected from a mirror, may be employed. I have now used this instrument for some time for teaching in the wards, and it may be fitted up with pipettes, slides and cells in a leathern case. The instrument is made by Mr. Matthews, Portugal Street, Lincoln's Inn. (See also *How to Work with the Microscope*, illustrated edition, 1861.)

2. *An ordinary Student's Microscope*, with large stage. (*The Microscope in Medicine*, Figs. 13, 14.)

3. *Object Glasses required.* The quarter of an inch, magnifying about 200 diameters; and the inch, magnifying from 30 to 50 diameters.

4. *Stage Micrometer*, divided to 100ths and 1000ths of an inch.
5. *Neutral Tint Glass Reflector*, for tracing the outline of objects. It is very important that the observer should be familiar with the methods of drawing and measuring objects accurately. The arrangement of the microscope for this purpose will be understood by reference to Plate III. (See also the *Microscope in Medicine*, p. 33 *et seq.*)
6. *Balance*, to weigh to the 1-50th of a grain.*
7. *Weights.* It is better to be provided both with gramme and also with grain weights.
8. *Microscope Lamp.* An ordinary French lamp gives a very good artificial light. The best form of gas-lamp has been arranged by Mr. Highley. It is figured in Plate II, Fig. 71, and may be obtained of Mr. Matthews, Portugal Street, Lincoln's Inn.
9. *Test Bottles with Capillary Orifices*, referred to in Lecture XII. These may be obtained fitted up in a box with other apparatus, Plate II, Fig. 70; or separately, as represented in Plate VII, Figs. 94, 96, 97.
10. *Test-Tubes* of various sizes, with rack and drainer, Plate VII, Fig. 98.
11. *Test-Tube Holder*, represented in Plate II, Fig. 70.
12. *Small Retort-Stand*, Plate IV, Fig. 77.
13. *Tripod and Wire Triangle*, for supporting platinum capsule or platinum foil, while the organic matter is being burned off; Plate IV, Fig. 82.
14. *Spirit-Lamp*, Plate IV, Fig. 78.
15. *Water-Bath*, Plate IV, Figs. 80, 81. But where the observer desires to make careful analyses of urine, it is

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* A very efficient balance may be purchased of Mr. Becker, of the firm of Elliott Brothers, Strand, for the sum of £3.

better to be provided with a larger water-bath, so that four or five basins may be placed over it at one time. A little hot water drying oven will also be required, if quantitative determinations are to be made.

16. *Nest of Beakers.*

17. *Conical Glasses*, Plate v, Fig. 87; Plate vi, Fig. 90.

18. *Porcelain Evaporating Basins*, of various sizes, from eight ounce capacity to half an ounce capacity.

19. *Wash-Bottle*, for washing precipitates on filters; Plate vi, Fig. 92.

20. *Glass Funnels*, of various sizes; Plate v, Fig. 88.

21. *Filtering Paper*, Plate vi, Fig. 93.

22. *Glass Measures.* One pint measure; one four ounce; one one ounce; 1000 grain measure; cubic inch measure.

23. *Stirring Rods.*

24. *Test-Papers.* Blue litmus and reddened litmus.

25. *Urinometer*, Plate i, Fig. 67, B.

26. *Thermometer.*

27. *Blowpipe.*

28. *Pipettes*, of two or three sizes; Plate vi, Fig. 89.

29. *Glass Slides*, three inches by one inch.

30. *Thin Glass*, cut into squares and circles.

31. *Glass Cells*, for examining urinary deposits; Plate v, Fig 85. The animalcule cages, made in the forms figured in Plate v, Figs. 84, 86, will also be found very convenient for this purpose.

32. *Watch-Glasses*, of various sizes.

33. *Brass Forceps.*

34. *Filaments of Tow or Silk.*

35. *Reagents*, in two-ounce stoppered bottles. The solution of salts generally, from ten to fifty grains to the ounce of distilled water. Distilled water, HO, in a quart bottle.

a. Alcohol	HO,C^4H^5O
b. Sulphuric acid . .	HO,SO^3
c. Hydrochloric acid . .	HCl
d. Nitric acid . . .	HO,NO^5
e. Oxalic acid . . .	C^2O^3,HO
f. Acetic acid . . .	HO,C^4H^3, O^3
g. Ammonia . . .	NH^3
h. Oxalate of ammonia .	$NH^4O,C^2O^3+Aq.$
i. Potash	KO
k. Ferrocyanide of potassium	$K^2,FeCy^3+3Aq.$
l. Chloride of ammonium .	NH^4Cl
m. Lime water . . .	CaO,HO
n. Carbonate of soda .	$NaO,CO^2+10Aq.$
o. Phosphate of soda . .	$2NaO,HO,PO^5+24Aq.$
p. Chloride of calcium .	$CaCl$
q. Chloride of barium .	$BaCl$
r. Perchloride of iron .	Fe^2Cl^3
s. Sulphate of copper .	$CuO,SO^3+Aq.$
t. Nitrate of silver . .	AgO,NO^5
u. Bichloride of mercury .	$HgCl^2$
v. Bichloride of platinum .	$PtCl^2$
w. Barreswil's solution	

Most of the apparatus and the principal tests enumerated may be obtained of Mr. Matthews, Portugal Street, Lincoln's Inn; Messrs. Griffin, Bunhill Row; or Mr. Baker, Holborn. Messrs. Bullock and Reynolds, of Hanover Street, will supply the tests.

Fig. 65.

Fig. 69.

Fig. 67.

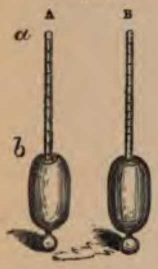


Fig. 68.

Fig. 66.

Fig. 65. Clinical pocket microscope, specially adapted for examining urinary deposits.
Fig. 66. The spring beneath the stage, which keeps the preparation in its proper position.
Fig. 67. Urinometers—A an imperfect instrument, in which the degrees on the stem are equally divided. B a good instrument, in which they gradually diminish in length from above downwards (p. 11).
Fig. 68. Specific gravity bottle, with tubulated stopper and counterpoise (p. 10).
Fig. 69. A useful form of compressorium for examining certain urinary deposits which require pressure, or thin sections of kidney, &c.

Fig. 70.

Fig. 71.

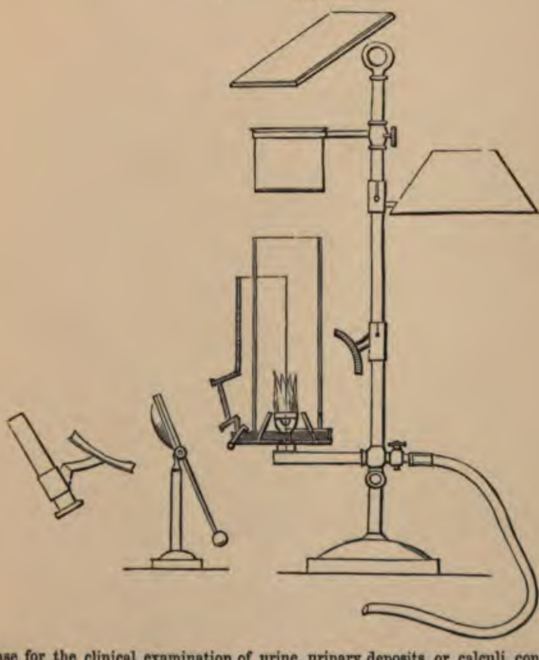


Fig. 70. Case for the clinical examination of urine, urinary deposits, or calculi, containing tests in bottles with capillary orifices, urinometer and glass measure, pipette, test tubes, spirit lamp and stand, glass slides, thin glass covers, watch glasses, test papers, forceps, tube holder, &c.

Fig. 71. Microscope gas lamp, as arranged by Mr. Highley.

PLATE III.

Fig. 72.

Fig. 73.

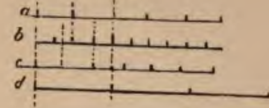


Fig. 74.

Fig. 75.

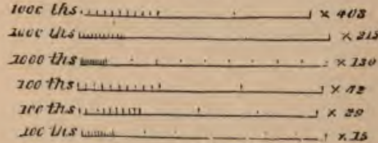
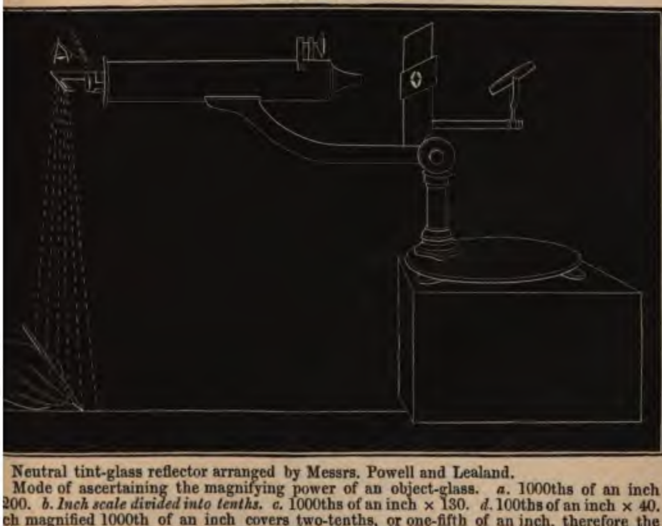


Fig 76.



Neutral tint-glass reflector arranged by Messrs. Powell and Lealand.
Mode of ascertaining the magnifying power of an object-glass. *a.* 1000ths of an inch 200. *b. Inch scale divided into tenths. c.* 1000ths of an inch × 130. *d.* 100ths of an inch × 40. ch magnified 1000th of an inch covers two-tenths, or one-fifth of an inch, therefore the ss magnifies 200 times, for $\frac{1}{1000} \times 200 = \frac{2}{10}$ or $\frac{1}{5}$ of an inch. Each 100th of an inch covers r-tenths of an inch, therefore the glass magnifies 40 times, for $\frac{1}{100}$th $\times \cdot 40 = \frac{4}{10}$ (p. 24).
Stage micrometer divided into 1000ths and 5000ths of an inch, magnified 215 diameters.
. 100ths and 1000ths of an English inch magnified in various degrees. The smallest isions are 1000ths and 10,000ths.
. To illustrate the arrangement of the microscope for drawing and measuring objects.

Fig. 77.

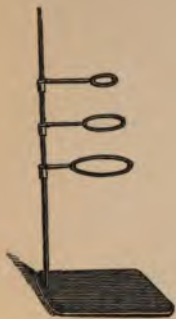


Fig. 78.

Fig. 79.

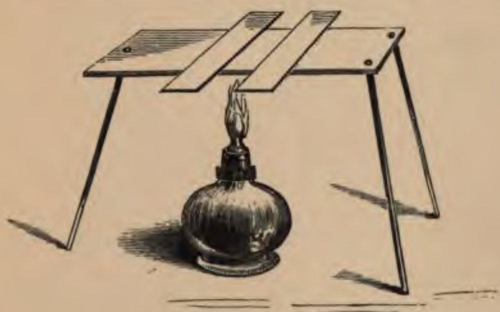


Fig. 80.

Fig. 81.

Fig. 82.

Fig. 77. Small retort-stand to support watch-glasses, &c.
Fig. 78. Spirit lamp with wire stand attached.
Fig. 79. Brass plate for heating glass slides when objects are mounted in Canada balsam (p. 219).
Fig. 80. Porcelain basins arranged for a water bath.
Fig. 81. Small copper bath, with ring to diminish aperture.
Fig. 82. Tripod wire stand for supporting platinum basin containing matter for incineration (p. 42).

Fig. 83

Fig. 84.

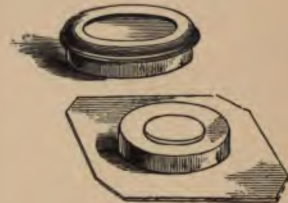


Fig. 85.

Fig. 86.

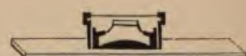


Fig. 87.

Fig 83.

Fig. 83. Apparatus for pressing down the thin glass cover while cements are drying, arranged by the Rev. G. Isbell.
Fig. 84. Animalcule cage for examining strata of fluids of different degrees of thickness (p. 216).
Fig. 85. Glass cell for examining urinary deposits (p. 216).
Fig. 86. Small cage, very convenient for examining urinary deposits (p. 216).
Fig. 87. Glasses for taking the specific gravity of urine and for allowing deposits to subside.
Fig. 88. Shows how filtration may be conducted.

Fig. 89.

Fig. 90

Fig. 92.

Fig. 91.

Fig. 93.

. 89. Pipettes made of glass tube for separating deposits from fluids (p. 213).
. 90. Illustrates the manner of using the pipette (p. 213).
, 91. Shows the manner in which a very small quantity of deposit may be obtained from a fluid, by placing it in a test tube, and inverting it over the glass slide. It is kept in position by an India-rubber band shown in the drawing (p. 214).
z. 92. Wash bottle.
g. 93. Illustrates the manner in which filtering paper is to be cut and folded for filtering.

Fig. 94.

Fig. 95.

Fig. 96.

Fig. 97.

Fig. 98.

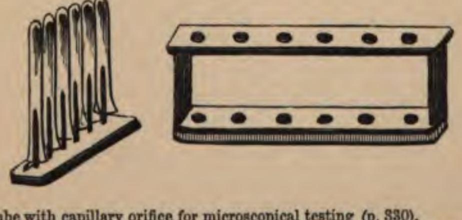
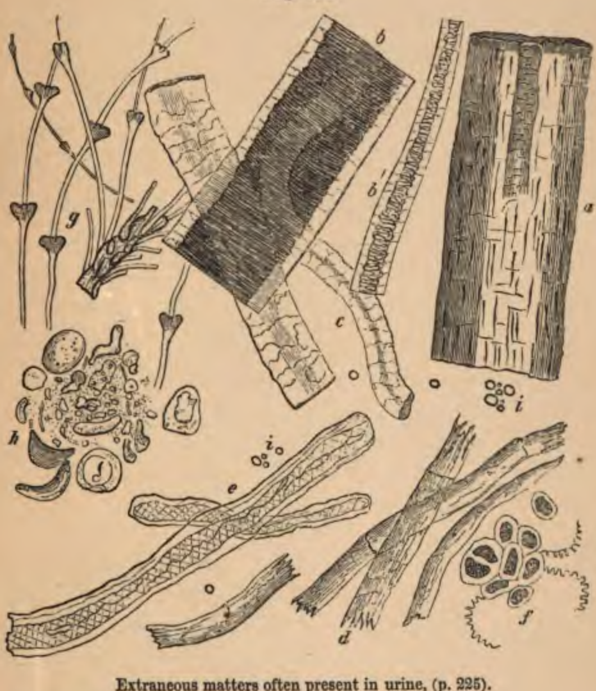


Fig. 94. Small tube with capillary orifice for microscopical testing (p. 330).
Fig. 95. Tube with India-rubber, *a*, tied over upper extremity, to remove small quantities of test solutions from bottles. *b*. Ground, to fit into the neck of the bottle. *c*. Orifice.
Fig. 96. Bulb with capillary orifice (p. 330).
Fig. 97. Box with test solutions in bottles with capillary orifices.
Fig. 98. Test tubes, rack, and drainer.

Fig. 99.

Fig. 100.

Fig. 101.



Extraneous matters often present in urine, (p. 225).

Fig. 99. Fibres of deal swept from the floor (p. 228).
Fig. 100. Globules of potato starch (p. 229).
Fig. 101. *a.* Fragments of human hair. *b.* Cat's hair. *c.* Hair from blanket. *d.* Fibres of flax. *e.* Fibres of cotton. *f.* Fragments of tea-leaves, showing cells and spiral vessels. *g.* Portions of feathers. *h.* Bread crumbs, showing wheat starch partly altered by baking and maceration. *i.* Free oil globules (pp. 227-28-29-30).

TABLES

FOR

THE SYSTEMATIC QUALITATIVE EXAMINATION OF URINE.

All those who desire to make themselves familiar with the most important characters of the urine, are strongly recommended to submit to the routine which a conscientious practice of the experiments given in the following tables necessarily involves. The author is fully persuaded that the patient prosecution of the course recommended, for two hours on eight or ten occasions, will enable the practitioner to obtain a practical familiarity with the subject, which it is impossible he can acquire by reading.

CHEMICAL AND MICROSCOPICAL EXAMINATION OF THE URINE IN HEALTH.

*** The works referred to in these tables are the present one, and the *Illustrations of Urine, Urinary Deposits, and Calculi.*

TABLE I.

General characters of Urine (Lecture I).

PLACE about 100 grains of urine in a basin to evaporate over the water bath.

1. COLOUR, SMELL, CLEARNESS OR TURBIDITY, DEPOSIT, FILM ON SURFACE.—Pour about four ounces of urine into a test-glass; take notice of its **colour** (p. 4) and **smell** (p. 6). Observe whether the specimen be **clear** or **turbid,** and notice the faint **mucous cloud** which collects on standing (p. 7). Observe whether there be any **deposit** which sinks to the bottom of the vessel, or **film** floating upon the surface of the fluid (pp. 232, 249).
2. SPECIFIC GRAVITY.—Take the **specific gravity** of the urine (p. 8).
   - α. Using the *urinometer* (p. 8, fig. 67, Pl. I).
   - β. Using the *specific gravity bottle* (p. 9, fig. 68).
3. REACTION.—Test the urine with *blue litmus* paper. 2. If the specimen exhibit no **acid reaction,** test it with *reddened litmus,* and observe whether the colour be restored upon gently warming the paper upon a strip of glass, **volatile alkali,** or not, **fixed alkali** (p. 11).
4. CRYSTALLINE SUBSTANCES IN URINE.—Place a drop of urine which has been *concentrated by evaporation* upon a glass slide, and cover it with thin glass. When cool, examine it under the microscope; note the form of crystals present, **urate of soda** (p. 33), **acid phosphate of soda** (p. 48), **basic phosphate of soda** (p. 48), **sulphate of soda** (p. 56), **chloride of sodium and urea** (p. 22), **ammoniaco-magnesian or triple phosphate** (p. 53), **granules of phosphate of lime** (p. 53). (*Illustrations, Urine,* Plate I.)

5. Decomposition by Heat.—Place a small portion of the *solid residue* (about the size of a pin's head) in a hard glass tube, and expose it to the flame of a spirit lamp, gradually raising the temperature to redness. Test the *reaction* of the vapour emitted from the tube with reddened litmus paper which has been moistened (p. 42).

6. Saline Constituents.—Remove the *carbonaceous residue* from the tube, and expose it upon platinum foil to a dull red heat, until nothing but a **white ash** remains (p. 43, fig. 82).

7. Alkaline Salts.—Place the ash upon a glass slide, and treat it with one drop of *distilled water*, applying warmth. Concentrate the aqueous solution by evaporation, and allow crystals to form. These should be covered with thin glass, and subjected to microscopical examination. **Chloride of sodium** (p. 59), **phosphate of soda** (p. 48), **sulphates of soda and potash** (p. 56). (*Illustrations, Urine*, Pl. I, fig. 1.)

8. Earthy Salts.—If the saline residue is not entirely dissolved by water, add a drop of nitric acid, and observe whether in effervescence **carbonate of lime** occurs, or if the *insoluble matter* is dissolved without the escape of any *bubbles of gas*, **phosphate of lime.**

9. Uric Acid.—Place about four ounces of urine in a beaker, add about a drachm of *hydrochloric acid*, and allow the mixture to stand for twelve hours. **Crystals of uric or lithic acid.** (p. 29.)

10. Uric Acid.—To a small quantity of the urine, concentrated by evaporation, and placed in a watch glass, add a few drops of *acetic acid*, and insert in the mixture a few *filaments of tow or silk*. Allow the whole to stand for twenty-four hours covered with a glass shade, in order to prevent the entrance of dust (p. 31). **Crystals of uric or lithic acid.**

*** The deposits from the urine examined in secs. 9 and 10 are to be examined in II.

TABLE II.

Systematic qualitative examination (p. 39).

The organic constituents (Lecture II).

11. REACTION.—SPECIFIC GRAVITY.—Ascertain the **reaction** and **specific gravity** of the specimen of urine, and note any general characters you may observe (Lecture I).

12. PLACE two portions, A and B, of about 300 grains each, in basins, to evaporate over the water bath (p. 39, fig. 81).

13. IN PORTION A.—UREA, MUCUS, URIC ACID, EXTRACTIVE MATTERS, EARTHY PHOSPHATE AND SILICA (p. 39).

14. IN PORTION B.—FIXED SALTS (Lecture III).

B is to be placed in a *platinum capsule* and incinerated (fig. 82, p. 42). The saline residue is to be maintained at a red heat, and when decarbonized is to be preserved for examination in Table III.

Proceed with portion A.

15. UREA.—$C^2H^4N^2O^2$. Extract A is to be treated with three successive portions of *Alcohol*, about the *sp. gr.* ·825, which are to be boiled upon the residue for a few minutes over the *water bath*. The alcoholic solutions are to be mixed together and concentrated by evaporation. The extract is to be treated with a little *water*, in order that it may be reduced to the consistence of *syrup* (pp. 20, 40).

a A little of the syrupy extract when cold is to be placed in a small basin and treated with a few drops of strong *Nitric Acid*, **nitrate of urea** $C^2H^4N^2O^2, HO, NO^5$. Examine the crystals thus formed in the microscope (p. 40, *Illustrations, Urine*, Pl. III).

b The remainder of the concentrated extract is to be placed over a *water bath* conveniently arranged (fig. 81), and treated with *crystals* of *oxalic acid* until no more are dissolved at a temperature of 200°. The mixture is then

permitted to cool, and after the crystals have been slightly washed with a little distilled water, they may be placed between folds of filtering paper, **oxalate of urea,** $C^2H^4N^2O^2,HO,C^2O^3$. 14. Examine a few of the crystals in the microscope (*Illustrations, Urine*, Pl. IV). After having been well pressed to absorb **extractive matters,** etc., the crystals are to be dissolved *in warm water*, and excess of **carbonate of lime** added to the solution, to decompose the **oxalate of urea.** When the mixture becomes *neutral* to *test paper*, it is to be filtered, and the clear solution, which consists of **urea** with a little colouring matter, concentrated by evaporation. **Urea and colouring matter** remain. The latter may be removed by dissolving the urea in water, and boiling the solution with animal charcoal, and subsequent filtration (p. 40).

The process of filtering is seen in fig. 88: the manner in which the paper is folded in fig. 93. The wash bottle for washing precipitates is represented in fig. 92.

16. Mucus, Lithic Acid, Earthy Phosphate, and Silica.—*The matter insoluble in Alcohol* (sect. 15), is to be treated with hot water to dissolve extractive matter, and filtered.

The residue on the filter is to be dried, and incinerated on platinum foil. The **mucus** and **uric acid** are destroyed.

When the residue, consisting of **phosphate of lime** and **silica** is decarbonized, it is to be treated with a drop of *nitric acid.* Observe whether effervescence occurs, **carbonate of lime** CaO,CO^2. A trace of **silica** remains undissolved (p. 40).

To the acid solution add a drop of *ammonia*, and note the result. Examine the precipitate in the microscope, and notice the crystals of **ammoniaco-magnesian or triple phosphate,** and the amorphous granules of **phosphate of lime** (p. 51), *Illustrations, Urinary Deposits*, Pl. IX, figs. 1, 2; Pl. XXI, fig. 4.

17. Uric Acid $C^{10}H^4N^4O^6$.—Examine the crystals deposited upon the sides of the vessel, and upon the filaments of *tow* or *silk* which were set aside in Table I., with the microscope, and note the form of the crystals (figs. 38, 39, *Illustrations, Urinary Deposits,* Plates V, VI, VII, VIII). Then collect them upon a *glass slide*, and divide them into three portions.

a. To the **first** add a little *solution of potash*, which dissolves the crystals, forming **urate of potash,** and afterwards excess of *acetic* $C^4H^3O^3,HO$, or *hydrochloric acid*, HCl. After a few minutes have elapsed, subject the deposit to microscopical examination. *Crystals of* **lithic or uric acid** $C^{10}H^4N^4O^6$ (p. 30, 2, p. 295, 1).

b. To the **second** portion add a drop of *nitric acid* HO,NO^5, evaporate the mass to dryness over the lamp, then allow it to cool and add a little *ammonia* NH^3, or expose the acid residue to the vapour of ammonia. A beautiful purple colour, owing to the formation of **murexide** $C^{12}N^5H^6O^8$ results (pp. 30, 295).

c. To the **third** portion add solution of *carbonate of potash* KO,CO^2+2Aq, which will dissolve the uric acid $C^{10}H^4N^4O^6$, but more slowly.

TABLE III.

Systematic qualitative examination (p. 65).
The saline constituents (Lecture III).

18. Alkaline and Earthy Salts.—Treat the residue resulting from the incineration of portion B in Dem. II. with boiling distilled water and filter (p. 65); reserve the residue for subsequent operations, sect. 23. Proceed with the ***clear solution***, which is to be divided into two parts, one consisting of *three-fourths* and the other of ***one fourth.***

The *fourth part* of the solution is to be divided into three *equal portions* (sect. 21).

ALKALINE SALTS.

19. Sulphuric Acid.—To about three-fourths of the clear solution add a few drops of *nitric acid*, HO,NO^5, and observe if *effervescence* occurs, **carbonate of soda** $NaO, CO^2 + 10Aq$. Next add to the solution, placed in a flask and heated over a lamp, a small quantity of a solution of *chloride of barium*, $BaCl + 2Aq$. Boil the mixture and separate the precipitate by filtration. **Sulphate of baryta,** BaO,SO^3 (p. 56).

While filtration is proceeding, pass on to sect. 21.

a. A small quantity of the white precipitate of **sulphate of baryta** is to be boiled in *caustic potash*, and another portion in strong *nitric acid*. It is insoluble in both.

20. Phosphoric Acid.—The solution filtered from the precipitate produced by *chloride of barium* is to be treated with excess of *ammonia* NH^3 and the mixture rapidly filtered, *avoiding exposure to air* as much as possible. **Phosphate of baryta** $^2BaO,HO,PO^5$ (pp. 54, 66).—*Concentrate* the clear solution by evaporation, and when reduced to a small bulk continue its further examination (sect. 22).

21. Chlorine, Phosphoric Acid.—To the *first portion* add a few drops of *nitric acid* and excess of a solution of *nitrate of silver* AgO,NO^5, **chloride of silver** $AgCl$ (p. 60.) Filter. To the solution carefully add *ammonia*, avoiding an excess, **phosphate of silver** $3AgO,PO^5$. Then add more *ammonia*, and afterwards *nitric acid* (p. 56).

Phosphate of silver is soluble in *ammonia* and also in *nitric acid*.
Chloride of silver is soluble in *ammonia*, but insoluble in *nitric acid*.

a. Phosphoric Acid *of the alkaline phosphates precipitated as* **ammoniaco-magnesian** or **triple phosphate.** To the *second* portion add a little of a solution of *muriate of ammonia* NH^4Cl, *ammonia* NH^3, and *sulphate of magnesia* MgO,SO^3. A precipitate of **phosphate of ammonia and magnesia** will take place, $^2MgO,NH^4O,PO^5$. This is insoluble in *ammoniacal salts* (p. 55).

b. Phosphoric Acid *of the alkaline phosphate precipitated as* **phosphate of lime.** To the *third* portion of the clear solution add a little of a solution of *chloride of calcium* $CaCl$, and *ammonia* NH^3. **Phosphate of lime** $^2CaO,HO,PO^5$ is precipitated.

Allow the two last precipitates to subside, and then remove a little with the pipette and subject them to microscopical examination. **Phosphate of lime** is amorphous, but the **ammoniaco-magnesian phosphate** is crystalline (p. 54). (*Illustrations of Urinary Deposits*, Pl. IX, figs. 1, 2, XXI, fig. 4.

22. Potash Soda.—Return to the examination of the solution obtained in sect. 20, in which the presence of **potash** KO and **soda** NaO is to be demonstrated. Add it to an excess of *ammonia* NH^3, and carbonate of ammonia $2NH^4O,3CO^2$, in order to precipitate the excess of *baryta* BaO. Filter. Evaporate the solution to *dryness* and gently ignite the residue in a *platinum capsule*. Dissolve what remains in water, and add a few drops of solution of *bichloride of*

platinum $PtCl^2$. Evaporate the mixture to dryness over the water bath (p. 61).

The *dry residue* is to be treated with successive portions of *alcohol*. **Potassio-chloride of platinum** $KCl,PtCl^2$ remains undissolved (p. 61).

The *alcoholic solution* is to be concentrated that crystals may form, **sodio-chloride of platinum** $NaCl,PtCl^2$. Examine both the crystalline deposits in *the microscope* under the influence of polarised light.

The crystals of **potassio-chloride of platinum** are *octohedral* and *do not* polarise, while the crystals of **sodio-chloride of platinum,** are *acicular* and *do* polarise.

EARTHY SALTS.

23. PHOSPHATE OF LIME, PHOSPHATE OF AMMONIA AND MAGNESIA.—Return to the examination of that portion of the saline residue insoluble in water (sect. 18).

Add a few drops of *nitric acid* NO^5 to the residue, and notice if *effervescence* takes place, **carbonate of lime** CaO, CO^2. Dilute the solution and filter. Reserve any insoluble matter for further operations (sect. 24).

a. To one portion of the clear solution add excess of *ammonia* NH^3, and examine the precipitate in the microscope. **Phosphate of lime** $8CaO,3PO^5$, and **phosphate of ammonia and magnesia** $2MgO,NH^4O,PO^5+12Aq$ (p. 55).

b. LIME, MAGNESIA.— To another portion of the acid solution add *ammonia* NH^3, and afterwards excess of acetic acid $C^4H^3O^3,HO$, and then *oxalate of ammonia* $NH^4O,C^2O^3 + Aq$, **oxalate of lime** CaO,C^2O^3. Boil and filter (p. 62).

Concentrate the clear solution by evaporation. When cold, add a little solution of *chloride of ammonium* NH^4Cl, and phosphate of soda $^2NaO,HO,PO^5+24Aq$. Well stir the mixture, and examine the crystalline deposit in the

microscope. **Triple or ammoniaco-magnesian** phosphate $^{2}MgO,NH^{4}O,PO^{5}+12Aq$. (*Illustrations of Urinary Deposits*, Plate IX, figs. 1, 2).

24. SILICA.—That portion of the *earthy salts* insoluble in water is to be boiled with a few drops of strong *nitric acid*, HO, NO^{5}, silica, SiO^{3} remains undissolved (p. 62).

IN THE SYSTEMATIC QUALITATIVE EXAMINATION OF HEALTHY URINE, commenced in Table II, the presence of the following substances has been demonstrated :—

In portion A,

Urea	**Extractive matters**
Uric acid	**Earthy phosphates**
Mucus	**Silica**

In portion B,

Chlorine	**Soda**
Sulphuric acid	**Lime**
Phosphoric acid	**Magnesia**
Potash	**Silica**

See also forms in pp. 41 and 67.

MICROSCOPICAL AND CHEMICAL EXAMINATION OF THE URINE IN DISEASE.

TABLE IV.

THE MICROSCOPICAL EXAMINATION OF URINARY DEPOSITS.

Insoluble matters and urinary deposits (Lectures VIII, IX, X, and XI.)

INSOLUBLE MATTERS may be divided into four classes:— (p. 210).

1. INSOLUBLE MATTER FLOATING UPON THE SURFACE OF URINE, OR DIFFUSED THROUGH THE FLUID.

2. LIGHT AND FLOCCULENT DEPOSITS, TRANSPARENT AND OCCUPYING CONSIDERABLE BULK (sect. 231).

3. DENSE AND OPAQUE DEPOSITS, OCCUPYING CONSIDERABLE VOLUME (sect. 231).

4. GRANULAR OR CRYSTALLINE DEPOSITS, SINKING TO THE BOTTOM, OR DEPOSITED UPON THE SIDES OF THE VESSEL (sect. 231).

Many of the most important urinary deposits are scarcely visible to the unaided eye, and can only be detected by careful microscopical examination.

For collecting urine for microscopical examination, see p. 212.

In examining a specimen of urine the microscopical characters, of the *pellicle* upon the surface, of any *insoluble matter* diffused through the fluid, as well as those of the *deposit* should be noticed. In many instances also it is necessary to examine the *deposit* in its *upper* part as well as that portion which sinks to the bottom of the vessel.

It is most important to be acquainted with the characters of those *extraneous matters* which are liable to fall into the urine accidentally, or which may have been placed there for the purpose of deceiving the practitioner. These are enumerated in sect. 29.

In the specimens arranged for examination will be found many of the substances enumerated below.

The *chemical reagents* required for examination are contained in the small *bottles with capillary necks* (sec. 300).

25. With the *pipette* (p. 213, fig. 89) remove a portion of deposit from the urine in the different conical glasses (figs. 87, 90), and place it upon a glass slide or in a thin glass cell (fig. 85), or in the animalcule cage (figs. 84, 86), and when carefully covered with thin glass, subject it to examination with the quarter of an inch object glass (p. 216).

What is the nature of the **urinary deposits** in the glasses numbered from 1 to 12, and the **extraneous** matters in glasses 13 to 20?*

I.—DIFFUSED THROUGH THE URINE AND NOT FORMING A DISTINCT DEPOSIT; OR, FORMING A THIN STRATUM OR PELLICLE UPON THE SURFACE OF THE URINE.

26. **Urates** (p. 233). (*Illustrations*, Pl. VIII.)

Fatty matter in a state of *extremely minute division* as it occurs in *chylous urine* (p. 234, fig. 23).

Vibriones, usually present only in urine which has been kept for some time, but occasionally found soon after the urine has been passed (p. 233). (*Illustrations*, Pl. XIX, fig. 3.)

27. **Film** composed of **phosphate of lime** and **ammoniaco-magnesian or triple phosphate**, not unfrequently containing **oil globules** (pp. 232, 249).

Torulæ occurring in *diabetic urine* (p. 256).

---

* The nature of the substances placed in the glasses is seen by reference to the following sections.

II.—FIRST CLASS OF URINARY DEPOSITS (Lect. IX).

28. **Mucus** (p. 253, fig. 24).

Epithelium—from the *convoluted portion* of the uriniferous tubes; from the *straight portion;* from the *pelvis of the kidney;* from the *ureters;* from the *bladder;* from the *urethra;* from the *vagina* (sect. 236); epithelium containing *oil* (p. 259, figs. 25, 26). (*Illustrations*, Pl. XXIV.)

Spermatozoa (p. 260, fig. 27). (*Illustrations*, Pl. XIII.)

Vibriones (p. 255). *Illustrations*, Pl. XIX, fig 3.)

Torulæ—*sugar torula* (p. 256); *pencillum glaucum* (p. 256.) (*Illustrations*, Pl. XIX, figs. 4, 5, 6.)

Sarcina (p. 258). (*Illustrations*, Pl. XIX, fig. 2.)

Casts of the uriniferous tubes (p. 263). *Casts of medium diameter, about the* 1-700*th of an inch* (p. 265).

Epithelial casts. Pale and slightly *granular* casts. *Granular* casts. Casts containing *pus, blood, crystals of oxalate of lime*, or *lithic acid.* Casts containing *oil* (p. 265). (*Illustrations*, Pl. XIV, figs. 1, 2, XVIII, fig. 1).

Casts of considerable diameter, *about* 1-500*th of an inch.*

Large and perfectly *transparent* casts. *Darkly granular* casts. Casts containing numerous *cells*, often enclosed as it were in a perfectly transparent tube (p. 268, fig. 29). (*Illustrations*, Pl. XIV, fig. 5, XVI.)

Casts of small diameter, about the 1-1000*th of an inch.*

Small waxy casts, perfectly clear in every part. Casts containing *epithelium, blood, pus, or oxalate of lime* (p. 269). (*Illustrations*, Pl. XIV, fig. 6).

III.—SECOND CLASS OF URINARY DEPOSITS (Lecture X).

Urate of soda with various colouring matters—red, pink, nut-brown, &c., with small quantities of **urates of ammonia, lime, and magnesia** (p. 274). *Illustrations*, Pl. VIII, figs. 1, 2, 5, 6.)

Pus (p. 278, figs. 31, 32).

Phosphates, consisting of **phosphate of lime** and **phosphate of ammonia and magnesia**, or **triple phosphate** (p. 283, figs. 33, 34, 35, 36, 37). (*Illustrations*, Pl. IX, figs. 1, 2).

IV.—THIRD CLASS OF URINARY DEPOSITS (Lecture XI).

Uric or lithic acid in various forms (p. 291, figs. 38, 39). (*Illustrations*, Pl. IV, V, VI, VII.)

Oxalate of lime occurring in the form of *octohedra* (p. 298), or of *dumb-bells* (p. 300, figs. 40, 41, 42). (*Illustrations*, Pl. XII, XIII.)

Cystine (p. 308, fig. 43). (*Illustrations*, Pl. X.)

Carbonate of lime (p. 312).

Blood corpuscles (p. 213, fig. 44).

29. THE MOST IMPORTANT EXTRANEOUS MATTERS accidentally present in the urine, or which are sometimes added for the purposes of deceiving the practitioner, are the following (Lecture VII, p. 225).

Human hair (fig. 101, *a*)
Cat's hair (fig. 101 *b*)
Blanket hair (fig. 101 *c*)
Worsted (fig. 101)
Wool
Cotton and flax fibres (fig. 101 *d e*)
Splinters of coniferous wood swept from the floor (fig. 99)
Portions of feathers (fig. 101 *g*)
Fibres of silk
Milk and certain colouring matters
Oily matter (fig. 101 *i*)
Potatoe starch (fig. 100)
Wheat starch
Rice starch
Tea leaves
Bread crumbs (fig. 101 *h*)
Chalk or whitening
Sand
Peroxide of iron

See also *Illustrations*, *Urinary Deposits*, Pl. I, II, III.

TABLE V.

Substances held in solution in Morbid Urine (Lecture V).

Albumen, excess of urea, bile.

41. Ascertain the *reaction* and *specific*] *gravity* of the specimens of Urine marked A, B, C, D.

42. Albumen.—Boil a portion of the Urine in a test tube over a *spirit lamp* and observe the character of the precipitate, if one is formed.

a. Treat a **second** portion with about 10 drops of nitric acid (p. 133).

If no precipitate is produced upon the addition of nitric acid, or upon the application of heat, pass on to sect. 43.

b. A **third** portion to be treated with half its bulk of *strong nitric acid*, and boiled.

c. To a **fourth** portion add 2 drops of very *dilute nitric* acid, and afterwards boil.

A very dilute solution of nitric acid prevents the precipitation of albumen by heat (p. 134).

d. A **fifth portion** is to be treated with a little *acetic acid* $HO,C^4H^3O^3$, and afterwards a solution of *ferrocyanide of potassium* $K^2,FeCy^3+3Aq$ is to added (p. 138).

e. To a **sixth** portion add a solution of *bichloride of mercury* $HgCl^2$ (p. 138).

43. Excess of Urea $C^2H^4N^2O^2$.—Add to the specimen of urine suspected to contain excess of *urea* from its deep colour and high specific gravity, about half its bulk of *nitric acid* HO,NO^5. Allow it to stand for a few minutes, and examine the crystalline deposit which forms in the microscope, **nitrate of urea,** $C^2H^4N^2O^2,NO^5$ (p. 89).

44. SUGAR.—*a.* **A portion** of the Urine suspected to contain sugar is to be boiled in a test tube with half its bulk of solution of *potash* KO,HO (*Moore's test*). If it becomes of a dark reddish brown colour from the formation of *melassic* or *sacchulmic acid*, it is to be treated with excess of *nitric acid*, when the peculiar odour resembling that of *molasses* will be produced, and the dark brown solution will become perfectly clear (p. 151).

b. A **second portion** is to be treated with one or two drops of a solution of *sulphate of copper* CuO,SO^3+5Aq, and afterwards a considerable excess of *potash* KO,HO is to be added. The *dark blue solution* is then to be heated over the spirit lamp and boiled for a moment, when a yellowish brown **precipitate** of *suboxide of copper* Cu^2O, will be produced [*Trommer's test*] (p. 151).

c. A **third** portion is to be heated with about an equal bulk of the solution of *tartrate of copper* in *potash*, **Barreswil's solution*** (p. 153).

d. **Fermentation.**—Fill one of the tubes placed on the table with Urine, and the other with water, to each add six drops of *yeast*, and then a little more Urine and water, in order that the fluids may rise above the brim of the tubes. Apply the *indiarubber pad*, and invert them in the small beakers. Remove the indiarubber and add some mercury. Place the whole in a temperature of 80°, and, after the lapse of two hours, compare the size of the bubbles of gas in the respective tubes (p. 158).

---

* Bernard's modification of this solution, which may be used in determining the *quantity* of sugar, is made as follows:—

Cream of Tartar	2316 grs.
Crystallized carbonate of soda	2316 grs.
Caustic potash	1544 grs.
Sulphate of copper	772 grs.
Water	35 oz. 1½ dr.

Leçons de Physiologie Expérimentale, 1853, p. 56.

e. **Crystals.**—Allow a few drops of diabetic urine to evaporate spontaneously upon a glass slide, and examine the residue on the next day to see if crystals have formed (fig. 6, p. 150).

45. **Bile.**—*a.* One portion of the Urine is to be placed in a test tube, and after the addition of one drop of *syrup*, two-thirds of its bulk of strong *sulphuric acid* SO^3,HO are to be added *cautiously by drops.* Shake the mixture, and allow it to stand for a few minutes. If sufficient heat is not produced by the addition of the acid, warm the tube slightly over the lamp. The mixture becomes of a *dark violet colour*, which, however, is destroyed by a temperature a little above 140° [*Pettenkofer's test*] (p. 144).

b. Pour a few drops upon a *clean white plate*, and after spreading it over the surface, allow a drop of *nitric acid* to fall in the centre. Observe the **play of colours** (p. 145 *a*).

c. To another portion add a few drops of *serum*, and, after agitation, a little *nitric acid* NO^5,HO. Observe the colour of the coagulated albumen [*Heller's test*] (p. 145 *b.* 2).

TABLE VI.

Chemical Examination of Urinary Deposits.

30. III. SECOND CLASS OF URINARY DEPOSITS (Lecture X).

Pus,
Urates or Lithates,
Phosphates.

31. OBSERVE the characters of the urinary deposits in the glasses A, B, C, and note the *colour*, *reaction*, and *specific gravity* of each specimen.

32. AFTER having poured off the *supernatant fluid*, take about *one-fourth* of the *deposit* from each glass, and pour it into a test tube. Add to it about half its bulk of *solution of potash* KO,HO.

Pus is rendered *transparent*, *viscid*, and *glairy* by *potash* (p. 273).

Urates are dissolved by *potash*, but the solution is perfectly *clear* and *limpid*.

Phosphates are not affected by *potash*.

33. URATES OR LITHATES.—If the deposit be soluble in *potash* KO, and not rendered *glairy*, take another portion and heat it in a clean test tube with a little water. It will be *dissolved* upon the application of a *gentle heat*, and will be *precipitated* again when the solution becomes *cool*. Another portion may be dissolved in *potash* KO, and then excess of hydrochloric acid HCl, or acetic acid $C^4H^3O^3$,HO, added. After the lapse of *ten* or *twelve hours* the deposit, consisting of **uric acid** $C^{10}H^4N^4O^6$, may be subjected to *microscopical examination*, or tested in the manner described in sect. 17 *a*, *b* (p. 274).

34. Pus.—If the deposit be rendered *glairy* by *potash* KO, note carefully its *microscopical characters* under the quarter of an inch object glass, and then add a drop of *acetic acid* $C^4H^3O^3,HO$, and observe the change which takes place in the appearance of the corpuscles. Notice if any crystals of *triple phosphate* $^2MgO,NH^4O,PO^5+12Aq$ are present in the deposit, and observe the character of any *epithelium* that may be met with (pp. 259, 283).

A small portion of the supernatant fluid is to be treated with *nitric acid* HO,NO^5, and another portion boiled in a test tube. The precipitates consist of **albumen** (p. 132).

35. Earthy Phosphates.—If the deposit consists of earthy phosphates, it will not be altered by *potash* KO, nor by the *application of heat*. A portion of it is to be treated with *nitric acid* HO,NO^5, in which it is soluble without effervescence.* Observe its microscopical characters (sect. 246). If there are no well defined crystals, dissolve a portion in dilute *nitric acid*, and then add excess of *ammonia*. Upon microscopical examination, the precipitate will be found to consist of feathery crystals of **triple phosphate** and granules of **phosphate of lime** (p. 283).

IV.—Third Class of Urinary Deposits.

Uric or Lithic Acid,
Oxalate of lime,
Sand.

36. Observe the character of the *deposits* in the glasses D, E, F, and note the *colour, reaction*, and *specific gravity* of the fluid in each case.

---

* If effervescence occurs upon the addition of nitric acid, it probably depends upon the presence of carbonate of ammonia, resulting from the decomposition of urea, a change very liable to occur in disease of the bladder, in which case the mucus appears to act the part of a *ferment*.

37. IF THE DEPOSIT is very small in quantity, remove it in the manner described in p. 214, and place it in a small watch glass or in the cell (fig. 85).

Uric or Lithic Acid is dissolved by *potash*, while **Oxalate of lime** and **sand** are not affected by this reagent. **Oxalate of lime** is insoluble in *acetic acid* and *potash*, but is dissolved by *nitric acid*. **Sand** is not affected by *potash*, nor by strong *nitric acid*.

38. URIC OR LITHIC ACID $C^{10}H^4N^4O^6$.—If the deposit is soluble in potash KO, treat a portion of it with nitric acid HO,NO^5, upon a glass slide, and carefully evaporate it to dryness over the *spirit lamp*. When cool, expose the residue to the vapour of ammonia, or add to it a drop of that reagent. The beautiful purple colour which results, depends upon the formation of Murexide $C^{12}N^5H^6O^8$, 23 (sect. 17, *a*, *b*, *c*, also p. 295, and *Illustrations*, Pl. IV, V, VI).

39. OXALATE OF LIME CaO,C^2O^3+2Aq.—If the deposit is insoluble in *potash* KO, and also in acetic acid $C^4H^3O^3,HO$, but is dissolved by nitric acid HO,NO^5, collect a portion of it upon a filter, and after having been well washed, let it be *dried* and carefully incinerated on *platinum foil*. To the *white ash* add a drop of *acetic acid*, and note the result. Examine a portion of the *original deposit* in the microscope (p. 297, *Illustrations*, Pl. XI, XII).

Oxalate of lime is decomposed, at a dull red heat, into **carbonate of lime** CaO,CO^2.

40. SAND.—If the deposit is insoluble in *potash* KO,HO, *acetic acid* $C^4H^3O^3,HO$, *nitric acid* HO,NO^5, boil it in strong *nitric acid*, and examine it under the microscope.

OF URINARY CALCULI, AND THE EXAMINATION OF SMALL QUANTITIES OF DEPOSITS IN THE MICROSCOPE.

TABLE VII.

Urinary Calculi.

1. *Those which are not destroyed by a red heat.*

Incombustible calculi.

Phosphate of lime $8CaO,3PO^5$; **phosphate of ammonia and magnesia or triple phosphate** $2MgO,NH^4O,PO^5$; **fusible calculus consisting of a mixture of phosphate of lime and triple phosphate.**

2. *Those which are partially decomposed, or entirely destroyed by a red heat.*

Combustible or partially combustible calculi.

Uric or lithic acid $C^{10}H^4N^4O^6$; **uric or lithate of ammonia** $NH^4O,C^{10}H^4N^4O^6$; **urate of lime** $CaO,C^{10}H^4N^4O^6$; **oxalate of lime** $CaOC^2O^3$; **cystine** $C^6NH^6O^4S^2$.

If the calculus consists of several different layers, a portion from each layer should be finely powdered and examined separately.

MICROSCOPIC CALCULI.—*Illustrations, Calculi*, Pl. I.

46. URINARY CALCULI.—Heat a portion of the calculus, about the size of a pin's head, on *platinum foil*, over the spirit lamp. Expose the *black ash* thus obtained for some time to a *dull red heat* until the residue becomes *white*. If there should be *no fixed residue* pass on to 50.

Calculi which leave a fixed residue.

47. FUSIBLE CALCULUS.—The white ash is to be exposed to the heat of the blowpipe flame. Observe if it be fusible or infusible. 392.

48. Phosphate of Lime, Ammoniaco-magnesian Phosphate. The ash is to be dissolved in dilute *hydrochloric acid* HCl,HO. If *effervescence* occurs upon the addition of the acid pass on to sect. 49. Neutralize with *ammonia* NH^3. Examine the precipitate in the microscope. 391. Sect. 246.

a. Carbonate of lime results from the decomposition of *oxalate of lime*, **mulberry calculus**, at a red heat.

49. Oxalate of Lime.—If effervescence occurred upon the addition of the *acid*, the solution is to be neutralised with *ammonia*, and afterwards excess of *acetic acid* added. To the solution add oxalate of ammonia NH^4O,C^2O^3+Aq, **oxalate of lime** Ca,OC^2O^3 is thrown down. This is insoluble in *potash* KO,HO, and in acetic acid $HO,C^4H^3O^3$. 399.

Calculi which leave scarcely a trace of fixed residue.

50. Urate Calculus.—A small portion of the calculus finely powdered is to be treated with hot water. If soluble in that fluid a strong solution of *carbonate potash* is to be added, and the tube heated over the lamp. Ascertain the reaction of the fumes which are given off. Notice their smell, and hold a rod which has been dipped in hydrochloric acid over the mouth of the tube.

51. Uric Acid Calculus.—If *insoluble in water* also add a little *potash*. If soluble in the last reagent, treat another portion of the calculus with *nitric acid and ammonia*, as described in sect. 17, *b*. This test may also be applied in case of a calculus supposed to consist of urate of ammonia.

METHOD OF TESTING VERY SMALL QUANTITIES OF MATTER WITH REAGENTS KEPT IN SMALL BOTTLES WITH CAPILLARY ORIFICES (Figs. 94, 96, 97, 98).

52. Phosphate of Lime, Chloride of Sodium, Phosphate of Soda, Sulphate of Potash.—What is the nature of the substance upon the glass slides marked A, B? Test it with such reagents as you think requisite.

What substances are dissolved in the drops of water marked C, D, E?

WEIGHTS AND MEASURES.

TROY OR APOTHECARIES' WEIGHT.

Pound.		Ounces.		Drachms.		Scruples.		Grains.		French Grammes.
1	=	12	=	96	=	288	=	5760	=	372.96
		1	=	8	=	24	=	480	=	31.08
				1	=	3	=	60	=	3.885
						1	=	20	=	1.295
								1	=	0.0647

AVOIRDUPOIS WEIGHT.

Pound.		Ounces.		Drachms.		Grains.		French Grammes.
1	=	16	=	256	=	7000	=	453.25
		1	=	16	=	437.5	=	28.328
				1	=	27.343	=	1.77

IMPERIAL MEASURE.

Gal.		Pints.		Fl. ounces.		Fl. drms.		Minims.
1	=	8	=	160	=	1280	=	76800
		1	=	20	=	160	=	9600
				1	=	8	=	480
						1	=	60

WEIGHT OF WATER AT 62°, CONTAINED IN THE IMPERIAL GALLON, ETC.

		Grains.
1 Imperial Gallon .	= .	70,000
1 „ Pint .	= .	8750
1 „ Fluid Ounce .	= .	437.5
1 „ Fluid Drachm	= .	54.7
1 „ Minim .	= .	0.91

CUBIC INCHES CONTAINED IN THE IMPERIAL GALLON, ETC.

		Cubic Inches.
1 Imperial Gallon .	= .	277.273
1 „ Pint .	= .	34.659
1 „ Fluid-ounce .	= .	1.732
1 „ Fluid-drachm	= .	0.2166
1 „ Minim .	= .	0.0036

FRENCH WEIGHTS AND MEASURES.

MEASURES OF LENGTH.

		English Inches.		Mil.	Fur.	Yds.	Feet.	In.
Millimetre	=	.03937						
Centimetre	=	.39371						
Decimetre	=	3.93710						
Metre	=	39.37100						
Decametre	=	393.71000	=	0	0	10	2	9.7
Hecatometre	=	3937.10000	=	0	0	109	1	1
Kilometre	=	39371.00000	=	0	4	213	1	10.2
Myriometre	=	393710.00000	=	6	1	156	0	6

MEASURES OF CAPACITY.

		Cubic Inches.		English Imperial Measure. Gal.	Pts.	F. oz.	F. drm.	Min.
Millilitre	=	.06102	=	0	0	0	0	16.3
Centilitre	=	.61028	=	0	0	0	2	42
Decilitre	=	6.10280	=	0	0	3	3	2
Litre	=	61.02800	=	0	1	15	1	43
Decalitre	=	610.28000	=	2	1	12	1	16
Hecatolitre	=	6102.80000	=	22	2	1	4	48
Kilolitre	=	61028.00000	=	220	0	12	6	24
Myriolitre	=	610280.00000	=	2200	7	13	4	48

MEASURES OF WEIGHT.

		English Grains.		*Avoirdupois.* Poun.	Oun.	Dram.
Milligramme	=	.0154				
Centigramme	=	.1544				
Decigramme	=	1.5444				
Gramme	=	15.4540				
Decagramme	=	154.4402	=	0	0	5.65
Hecatogramme	=	1544.4023	=	0	3	8.5
Kilogramme	=	15444.0234	=	2	3	5
Myriogramme	=	154440.2344	=	22	1	2

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